SOCIETY FOR THE DIFFUSION OF USEFUL KNOWLEDGE

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NATURAL PHILOSOPHY.

IV.

CHEMISTRY.	ANIMAL PHYSIOLOGY.
BOTANY.	ANIMAL MECHANICS.

WITH

AN ANALYTICAL INDEX.

UNDER THE SUPERINTENDENCE OF THE SOCIETY FOR THE DIFFUSION OF USEFUL KNOWLEDGE.

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CHEMISTRY.

Introduction.

The science of Chemistry, in its most comprehensive sense, is so extensive in its views, that it is necessary to premise a few remarks upon the objects and limits of the following Treatise. All the forms of matter existing upon this earth are capable of being submitted to chemical examination; but this class of investigations carries us even beyond the confines of this globe, and embraces the interesting subjects of light, heat, and electricity. The mere index of a complete system of Chemistry would occupy the space of more than one number of these essays; any detailed examination of so large a field would, therefore, obviously far exceed the range of our present plan. A subject so extensive admits of many subdivisions; these form the objects of separate Treatises, which have been already published, such as Heat, Electricity, Galvanism, Thermometers; or will be hereafter published, as, Animal and Vegetable Chemistry, Crystallography, Chemical Analysis, Metallurgy, Electro-Chemistry, Gaseous Chemistry, &c.

Our object in the present Treatise is to explain the first principles of Chemistry strictly so called; and, in so doing, we shall endeavour, as much as possible, to simplify the subject; and to illustrate it by reference to common experience, or such simple experiments as every one might make with implements and substances commonly to be met with. The study of Chemistry is too often supposed to imply a difficult and abstruse pursuit, and the necessity of a provision of scarce materials and expensive apparatus; and to be adapted only to those who have it in their power to devote themselves entirely to the subject: but we are of opinion that the general principles of the science may be learnt from operations which are constantly going on around us, or which we can command at pleasure; and with which it would highly benefit every one, whatever his station in life, to become acquainted. That so many persons, not uninformed in other respects, should remain heedless and ignorant of the constitution of those commonest forms of matter amongst which their lot is cast, and upon which their existence depends, shows an indifference to things of the highest interest, which is irrational; and can be accounted for only by some defect in the common systems of education. Numbers there are, far above the lower classes, who still consider the elements of all things as consisting of Earth, Air, Fire, and Water; an error which classical learning, no less than the expressions of common parlance, tends to perpetuate. Let us hope that the days are at hand, if not already arrived, in which the acquirement of such fundamental knowledge will be looked upon as at least equally necessary with the study of languages, and the cultivation of taste and imagination.

The condensation requisite in this work obliges us to exclude, from the following pages, all historical details; all mention even of the names of those great philosophers by whose labours the science has been built; and all topics of controversy: and we shall confine ourselves to giving a faithful description of the phenomena of nature; pointing out their connexion with each other, and offering the best explanation of their mutual relations, of which the present state of our knowledge allows. Our allotted space will thus be devoted to the more useful portions of the science, while we are compelled to sacrifice much of the interesting and entertaining. But for the sake of those who have the opportunity of pursuing the science further, we shall endeavour to obviate the defects of such a plan, by appending a select list of the best works of reference.

Chapter I.

On Attraction and Repulsion, Chemical Affinity and Decomposition.

(§ 1.) All the phenomena of the material universe may be ultimately resolved into two kinds of motion; namely, those resulting from the two principles of *attraction* and *repulsion:* in consequence of

which, the particles of matter approach or move from each other according to laws which the intellect of man has been able to develope, but the causes of which appear to be beyond his comprehension. We distinguish two principal modes in which bodies are affected by these opposite forces: in the first, motion is communicated to *masses* (or visible combinations of the ultimate atoms of bodies) at *sensible distances;* in the second, to the ultimate invisible *atoms* of bodies at *insensible distances.* To the former mode belong the attractions of *gravitation*, *electricity*, and *magnetism;* which we see exemplified respectively in the fall of a stone to the earth; the approach of light bodies to resinous substances, or glass, when rubbed; or of iron filings to a loadstone: to the latter may be referred the attraction of *cohesion;* of which we can form a correct idea from the strong adhesion, when pressed together, of the two halves of a leaden bullet which has been cleft asunder; and from the running together of two globules of clean quicksilver, when brought into contact, or of two drops of rain upon a pane of glass. In like manner, *repulsion* at *sensible* distances may be exemplified, by the force with which the particles of glass fly asunder in the common playthings called Prince Rupert's drops; by the flying off of the same light bodies which have been first attracted, after they have been some time in contact with an excited resin or glass, or by the recession from each other of the two similar ends of two magnetised needles: and *repulsion* at *insensible* distances, which is chiefly excited by heat, may be seen in the expansion of the fluid of a thermometer, when warmed by the hand, or the gradual swelling out of a bladder, partly filled with air, before a fire.

Attraction and repulsion, acting upon masses at sensible distances, form the particular study of natural philosophy (in the limited acceptation of the term); which also embraces the same phenomena acting at *insensible* distances upon particles of the *same nature;* as those of the globules of quicksilver, or of the air included in the bladder.

(§ 2.) The study of the effects of attraction and repulsion acting at *insensible distances* upon particles of *different* natures, constitutes the science of chemistry *. The solution of a lump of sugar, or of alum, in water, is an example of this species of attraction; and the power which determines the union of the sugar, or of the alum, with the water, is specially denominated *chemical affinity.*

(§ 3.) The attraction of cohesion, or that force which unites together particles of the *same* nature, and different modifications of which occasion the variations * of solids and liquids; as well as that power of repulsion, which is opposed to it, and which characterises the state of aëriform fluids are, in fact, both opposed to chemical attraction, or the force which combines particles of *different* natures: and common experience daily proves, that a lump of sugar, or crystals of salts, are much more readily dissolved in water, if previously broken down or pounded, than if left in that solid form which the cohesion of their particles imparts. Instances will be hereafter pointed out, which will prove that the strongest chemical affinity may be held in check until cohesion has been destroyed.

The following experiment beautifully illustrates the opposite action of these two attractions:—Place a lump of alum, of a nearly prismatic form, in a glass of water, and carefully watch, from time to time, for some days, the progress of its solution. At first, the water acts with so much energy as to overcome the cohesion of the solid in every direction alike; but as the particles of the alum become united with those of the water, the power of the solvent diminishes; and the lump of alum assumes a pyramidal shape, with the narrow end upwards. The reason of this change of form is, that the particles of water which combine first with the alum become heavier from the union, and fall to the bottom of the glass; and the action at the lower extremity ceases before it is complete at the upper. When the action has nearly terminated, if we closely examine the lump, we shall find it covered with geometrical figures, cut out, as it were, in relief upon the mass; shewing, not only that cohesion resists the power of solution, but that, in the present instance, it resists it more in some directions than in others; and that, when the attraction of the solvent is nearly satisfied, it is balanced by that delicate modification of

* The word chemistry is of Arabic origin, in which language it signifies "the knowledge of the composition of bodies."

* See the Treatise on Heat for an explanation of the cause of vaporization, liquefaction, &c.; and the Treatise on Pneumatics for the mechanical properties of air, &c.

cohesion upon which crystalline arrangement depends. The consideration of the interesting phenomena of crystallization, however, forms one of the necessary subdivisions of our subject, and will be enlarged upon in a separate Treatise, in which the results of the present experiment will be further discussed.

(§ 4.) It will be convenient to distinguish three degrees of chemical attraction;—the result of the first and lowest degree is *mixture;* of the second *solution;* and of the third, and most energetic, *composition.* We shall endeavour to illustrate the distinctive characters of each of these modifications, and also to give a general idea of the various methods of *decomposition* arising from chemical repulsion; and in so doing, we shall hope to present such a preliminary view of affinity, as may assist the further progress of the student. It must, at the same time, be borne in mind, that the developement of the subject can only be found in the full details of chemical science.

On Mixture.

(§ 5.) Chemical mixture can only take place between two bodies when the particles of both are in a like state, and the power of cohesion, with regard to them, so far suspended as to admit of that freedom of motion between themselves upon which fluidity depends: thus, two liquids, or two aëriform fluids may admit of mixture; but two solids can be chemically *mixed* only by diminishing their cohesion, by means of heat, to such a degree as to bring them both to the state of liquids.

Between some fluids there appears to be no attraction; and, consequently, they do not admit of mixture: thus, if water and oil be agitated together, they almost immediately separate, and the lighter liquid floats upon the denser. Sulphuric acid, or oil of vitriol, and water, on the contrary, have a strong affinity for each other, and, when mixed together, will not again separate by repose; although one fluid is very much heavier than the other. Alcohol, or pure spirit, and water form a mixture of the like permanent character; and many similar instances might be adduced.

(§ 6.) Of the mixture of aëriform bodies we have an example in the atmosphere which we breathe; which consists principally of two species of air mingled together with wonderful uniformity: they have received the names of oxygen and nitrogen gases. They may be separated, and the latter exhibited in a detached form, by burning a little sulphur in a quantity of the atmosphere confined in a bell glass over water. When this process is performed with care, the oxygen is removed and the nitrogen remains. Of the properties of these bodies this is not the place in which we propose to speak; but we shall only remark, at present, that the residual nitrogen differs so remarkably from the mixture from which it has been separated, as to be fatal to animal life, if breathed, and entirely to extinguish flame. The proportion which it bears to the total quantity upon which the experiment is tried is invariably the same. Unlike the case of liquids, all aëriform bodies have the property of mixing together. This difference in the two classes of bodies is to be ascribed to the different modification of the power of attraction between their constituent particles. In the instances where mixture does not take place between two liquids, as oil and water, or quicksilver and water, the still remaining attraction of cohesion between the similar particles is probably greater than the chemical attraction between the dissimilar particles. In aëriform fluids attraction of cohesion does not exist, (at least within the limits of common experience,) and the first degree of chemical attraction between the dissimilar particles comes into action unopposed.

The expansive power of heat being opposed to cohesion, the attraction between the particles of some bodies may be so far counteracted by its agency as to reduce them to the fluid state, and then they may admit of mixture: thus melted tin may be mixed with melted lead or copper, and their particles remain intermingled, when from a diminution of temperature they resume the solid state.

(§ 7.) Chemical mixture may take place between two bodies in any proportions. Equal measures of sulphuric acid and water may be mixed together; or one drop of the former with a gallon of the latter; or a drop of the latter with a gallon of the former, or in any intermediate proportions; and in every case the mixture will be perfect, uniform, and permanent. In like manner, oxygen and nitrogen may be mixed in any proportions, although the atmospheric mixture is always constant.

(§ 8.) Chemical mixture between liquids is often attended by condensation or contraction of volume: so that

a measure of sulphuric acid or of alcohol, mixed with an equal measure of water, will not quite fill two measures.

(§ 9.) Increase of temperature is also frequently another concomitant of the mixture of liquids. If four parts, by weight, of sulphuric acid, be suddenly mixed with one of water, at ordinary temperatures, the heat given out will be more than sufficient to make water boil.

(§ 10.) The properties of bodies are not essentially changed by mixture; but those of the resulting product are in some degree intermediate between their component parts: the character, however, of the more active ingredient will predominate, in a degree, of course, proportionate to its quantity. A few drops of sulphuric acid will communicate an intensely sour taste to a quart of water; but the same number of drops of alcohol will scarcely affect the sensible properties of an equal quantity of that fluid.

(§ 11.) The separation of liquid mixtures may be effected by either the addition or subtraction of heat; by the unequal effect produced upon the cohesive attractions of their ingredients. By carefully applying heat to a mixture of alcohol and water, the spirit will rise in vapour and leave the water pure; this process is called *evaporation*, where the elastic fluid is allowed to escape; but when it is separately recondensed and preserved, it is termed *distillation**. On the other hand, by the application of cold to a similar mixture, the cohesion of the particles of water may be so much more increased than that of the particles of the spirit, that the former will separate in a solid form, and leave the latter in a state of purity. It is thus that in the Arctic regions the watery particles of brandy are frozen by exposure to the air, and a very small quantity of strong spirit is left in the fluid state in the interior of the mass.

Mixtures of gaseous fluids cannot be separated by heat or cold, for they all expand in the same degree by equal increases of temperature: but steam and other vapours may be separated from gases by reduction of temperature; for the abstraction of heat destroys the elasticity of the former, but not of the latter. In this manner the aqueous vapour, which is always mixed in a greater or less proportion with the gases of the atmosphere, may be separated; and hence the origin of clouds and fogs.

* See the Treatise on HEAT for an explanation of the general principles of evaporation, distillation, &c.

On Solution.

(§ 12.) SOLUTION is the result of an affinity between bodies in different states with regard to cohesion. In this case liquids are called *solvents;* and they can act upon, or hold in solution, either solids or aëriform fluids. We have already alluded to instances of the solution of solids as illustrations of the general subject of affinity (§3); and we have shown that the power of cohesion is opposed to this action. Between some liquids and solids there appears to be no attraction whatever; or, if any, it is inferior to the attraction of cohesion by which the homogeneous particles of the solid are united; thus rosin is wholly insoluble in water, but readily unites with alcohol.

(§ 13.) And here we may remark, that chemical attraction, in general, may be exerted in different degrees between one body and several others. There is, as we have seen, a mutual affinity between alcohol and water, whereby they are capable of mixing; there is also a mutual affinity between alcohol and rosin, whereby the former is capable of dissolving the latter; and there is no affinity between water and rosin. Now if, to a solution of rosin in alcohol, water be added, it will be found that the rosin will resume the solid form: the attraction between the particles of alcohol and those of water, is greater than between the particles of alcohol and those of rosin; the consequence is, that the alcohol quits the rosin, and combines with the water, and the attraction of cohesion being no longer opposed, resumes its ascendancy. This has been called *elective attraction*, because the alcohol may figuratively be said to exercise a choice between the substances with which it is capable of combining. This resumption of the solid form of a substance, previously dissolved in a liquid, is termed *precipitation;* although the term can only be strictly applied where the solid, set at liberty, falls to the bottom of the vessel.

(§ 14.) Unlike the case of mixture, there is a limit to the power of solution; and liquids cannot combine with more than a certain definite quantity of any solid or aëriform body: thus water will only take up a certain known weight of alum, or alcohol of rosin. The point at which the action between the two bodies ceases, is called the point of *saturation*. Up to this point the two bodies may combine in any proportions.

Carbonic acid, or that aëriform substance, formerly known by the name of *fixed air*, which most persons are acquainted with, as given off from bottled beer or soda water, is capable of being absorbed by water; which liquid, under ordinary circumstances, will take up rather more than its own bulk of this air (or gas). As in the case of solids, the attractive power of cohesion, at a certain point, balances the action of the solvent, so, in aëriform bodies, the repulsive power of elasticity sets similar limits to its exertion. It is only to a certain point that the solvent power of water can counteract the elasticity of the carbonic acid; and beyond this point of saturation it cannot unite with it.

(§ 15.) The influence of heat upon the power of solution, corresponds with the difference between cohesion and elasticity. Upon solid bodies it generally *increases* the power of the solvent, by diminishing their *cohesion*. Upon aëriform bodies it *diminishes* the power, by adding to their *elasticity*. Water may be saturated with alum at the common temperature of the atmosphere, and if heat be afterwards applied, will dissolve an additional quantity; if the solution be then allowed to cool, the attraction of cohesion will resume its ascendancy, and the second portion of the alum will be deposited in solid and regular forms. If, on the contrary, a saturated solution of carbonic acid in water be heated, the gas will escape from its combination; for the heat increases the repulsive power of the particles of the gas, and the affinity of the solvent is no longer able to counteract it.

(§ 16.) A solvent that has been saturated with one substance, is often capable of combining at the same time with others; thus water which has taken up its full proportion of saltpetre, will further dissolve a considerable quantity of common salt.

(§ 17.) The process of the solution of a solid in a liquid, is very frequently accompanied by a diminution of temperature; and great degrees of cold may be produced by dissolving certain proportions of different salts in water. A reduction of 17° is produced, by merely saturating water at common temperatures with nitre; and nitrate of ammonia will, in the same way, lower the thermometer from 50° to 4°*. The solution of gases, on the contrary, is generally accompanied by the production of heat.

* See Treatise on Heat, p. 59.

(§ 18.) The properties of bodies are not changed by solution any more than by mixture; and the characters of such combinations are intermediate between those of their ingredients. The most universal solvent in nature is water; and as the characters of that liquid are very neutral, *i. e.* distinguished by no very energetic or active properties, aqueous solutions, in general, possess in an eminent degree the properties of the solids or gases with which they are combined.

(§ 19.) Solvents may be separated from the bodies with which they are united by alterations of temperature, which change their state of cohesion. If a solution of alum be strongly heated, or boiled, the liquid will assume the state of vapour, or of an elastic fluid, and flying off, the solid will remain. If a solution of carbonic acid in water be frozen, the gas will escape, and the water remain in the solid state. The affinities, however, of some gases for water are so strong, that they rise in union with its vapour, and cannot be separated by evaporation.

Chemical Composition.

(§ 20.) Composition is the result of the highest degree of chemical attraction; which may take effect between bodies whose particles are under every modification of cohesive attraction. The attractive force, however, of cohesion, as well as the repulsive power of elasticity, are in various degrees opposed even to this power; and till reduced or modified, often prevent its action altogether. The state of liquidity is consequently most favourable to its efficiency.

(§ 21.) The union of bodies in this intimate manner only takes place in *definite proportions*, which are invariable in the same compound, and it is commonly accompanied by a total change of their sensible properties. Great alterations of temperature almost always accompany the act of combination; and when the action is most energetic, light and heat are given off in abundance, and often with violence.

If copper filings and sulphur be mechanically mixed together, they will exhibit no tendency to unite at the common temperature of the atmosphere; but if heat be applied, as soon as the latter melts, a violent action will take place; the copper will become red hot, and a black, brittle body will be produced, with properties totally different from

those of its two ingredients. This compound is often found ready formed in mineral veins; but whether the product of nature or of art, as above described, its composition is definite and invariable; and it is found to consist of 64 parts of copper to 16 parts of sulphur: or 100 parts contain 80 copper and 20 sulphur. Our reason for preferring the statement of the proportion in the former numbers will hereafter appear.

(§ 22.) It often happens, however, that a body will unite in this manner in more than one proportion with another; the composition in each case being no less definite and fixed: but the proportion of one of the ingredients of the resulting compound is always some multiple or sub-multiple of that in the first compound; that is to say, it is double or treble, or half, and so on. Thus a second combination of copper and sulphur is known, which, although it cannot be produced by the direct union of the two bodies, is of very common occurrence, and constitutes the important ore from which nearly all the copper of commerce is derived. The proportions of this compound are 64 copper to 32 sulphur; that is to say, the copper is combined with exactly double the proportion of sulphur which exists in the first combination.

(§ 23.) The compounds which mercury or quicksilver forms with some other bodies, are well calculated to exhibit the striking difference of character which are the results, not only of chemical composition, but of composition in different proportions. If this brilliant, white, fluid metal be agitated for a long time in contact with the common air, it will unite with the oxygen of that mixture, and will be converted into a black, insipid, insoluble powder; which consists of 200 parts of mercury to 8 of oxygen. If, instead of being agitated at common temperatures with the air, it be kept heated with it to nearly its boiling point, it will be converted into a red, shining mass, also a compound of the metal and oxygen; but which is endued with an acrid, metallic taste, is soluble in water, and poisonous. It consists of 200 parts of mercury, and 16 of oxygen.

Mercury also combines with sulphur in two proportions: by long-continued trituration (or rubbing in a mortar) the two bodies unite, and form a black, tasteless compound, which contains 200 parts of mercury to 16 of sulphur.

If mercury be poured into melted sulphur, and strongly heated, a compound will be formed, which rises in vapour, and concretes, on cooling, into a brilliant red substance, known by the name of cinnabar or vermilion. It is composed of 200 parts of mercury, and 32 of sulphur.

Again, the well-known medicine called *calomel*, is a compound of mercury, and an aëriform substance, which we shall hereafter describe, called chlorine. This compound is white, crystalline, very heavy, tasteless, and nearly insoluble in water. It may be taken in doses of several grains without any effect, but that of a purgative. It is composed of 200 parts of the metal, and 36 parts of chlorine.

Mercury is capable of combining with a further proportion of the same gaseous body; in which case it is converted into a semitransparent, white mass, of an acrid, nauseous, metallic taste, soluble in water and alcohol, and highly poisonous. It is well known by the name of *corrosive sublimate*, and is composed of 200 parts of mercury, and 72 parts of chlorine.

Thus substances, comparatively inert, may produce, by their union, compounds of highly active properties; and a compound of two bodies, which, in one fixed proportion will, if taken internally, have but a slight effect upon the animal frame, if united in a different proportion, will prove destructive to life.

(§ 24.) Highly active bodies of opposite properties will also produce by their combination substances of mild character, and they are then said to neutralize each other.

Sulphuric acid, or oil of vitriol, to which we have before referred as a well-known liquid, for the purpose of illustrating the nature of chemical mixture, is highly corrosive, and possesses an intensely sour taste. If brought into contact with a substance stained with the delicate colour of any blue vegetable, such as that of violets or litmus, it instantly changes its tint to bright red; a property which belongs to all acids.

There is another substance, also well known, and commonly to be met with, called *Barilla*, or carbonate of soda. It is a solid, soluble in water, of a hot, acrid, bitter taste. It changes the blue colour of vegetables to green; a property which belongs to a class of bodies denominated alkalies. Between these two bodies a strong affinity subsists. If into a solution of the latter we carefully drop

a portion of the former, a brisk effervescence will ensue, and carbonic acid, or fixed air, will be given off, as from soda water. If the experiment be performed with care, and the dropping in of the acid stopped, the moment the effervescence ceases, the solution will be found to be warm, and to be possessed of properties totally different from those of the acid and the alkali from which it has been formed. It will not be sour, corrosive, acrid, nor hot. It will have no action upon blue vegetable colours, and all the active properties of the original bodies are said to be *neutralized*—they have *neutralized* one another. The product is slightly bitter, saline, and cooling. If part of the water be driven off by heat (or evaporated), a solid will be deposited in regular forms, which was previously held in solution by the water which escapes. This substance is known by the name of Glauber's salt, or sulphate of soda, and is extensively used in medicine.

(§ 25.) That power of affinity which produces chemical composition may, as in the case of solution, (§ 13) exist in a body in different degrees towards other bodies; and if to a compound of two bodies a third be presented which has a stronger attraction for either of the two ingredients than they have for each other, decomposition of the original compound will take place, and a new compound will result. Barilla, or carbonate of soda, to which we have just referred, is a compound of a highly caustic, alkaline substance, called soda and carbonic acid. In the experiment above alluded to it is decomposed; the sulphuric acid expels the carbonic acid, which escapes in effervescence, and takes its place with the soda. If a solution of this substance in water be boiled with caustic lime, the carbonate of soda will be decomposed, the carbonic acid will quit the soda and unite with the lime and carbonate of lime, or chalk, and caustic soda will be the result. This action is called, for the reason already explained, *single elective affinity.*

(§ 26.) If two compounds be brought together in solution, it will not unfrequently happen that a process of double decomposition and composition will take place, from a new adjustment of the various affinities: that is to say, the two original bodies will be decomposed, and two new compounds produced, from a mutual exchange of ingredients.

The substance known by the name of *sugar of lead*, is a compound of vinegar, or acetic acid and lead. *White vitriol* is composed of sulphuric acid and zinc. Now if, in a solution of the former substance in water, we suspend a piece of metallic zinc, we shall have an example of *single elective* affinity. The attraction of vinegar for zinc is greater than for lead; the acid will therefore abandon the lead, which will resume its metallic form, and unite with the zinc. The experiment is very beautiful as the lead is precipitated upon the zinc in an arborescent form. But if a solution of acetate of lead be mixed with a solution of sulphate of zinc, the acetic acid will, as before, abandon the lead to unite with the zinc; but at the same moment, the sulphuric acid will attract the lead, and form with it an insoluble compound, which will be precipitated in the form of a heavy white powder. This compound action has been distinguished by the name of *double elective affinity.* Decompositions which cannot be effected by *single elective* affinity may often be produced by *double elective* affinity.

(§ 27.) Now we may remark, that the same quantity of acetic acid which originally was combined with the lead, is exactly sufficient to enter into combination with the zinc; and also that the same quantity of sulphuric acid which entered into composition with the zinc, exactly suffices for the lead: none of the ingredients are found in excess, and the proportions of each are *equivalent* to each other in their power of combining. This observation exemplifies another fundamental law of chemical *composition;* namely, that bodies not only combine together in proportions which are fixed with regard to each other, in any given compound, but are also *definite* with regard to every other substance with which they are capable of entering into composition; so that there are certain determinate proportions of all bodies which are *equivalent* to each other in their powers of combining with all other bodies. Thus sugar of lead, or acetate of lead, is a compound of 50 parts of acetic acid and 112 parts of lead in the state (which will be hereafter explained) of an oxide. White vitriol, or sulphate of zinc, is composed of 40 parts of sulphuric acid, and 41 parts of zinc, also in the state of oxide. Now these proportions are all *equivalent* to one another; and if we write their numbers against the different substances as follows, we can at once perceive the proportions in

which they will unite in any new combination.

Sulphuric acid . .	40
Zinc (oxide) . . .	41
Acetic acid . .	50
Lead (oxide) . . .	112

Thus, from such a table we may anticipate, in the double decomposition above referred to, that the white powder or new compound of sulphuric acid, and lead, precipitated, must consist of 40 parts of the former and 112 of the latter; and likewise that the combination of zinc and acetic acid, left in solution, must be in the proportion of 50 parts of acid and 41 parts of zinc: and this exactly agrees with the results of experiment. We shall hereafter find that the same equivalent numbers, or their multiples, are preserved in every possible combination with other bodies; and that similar numbers may be attached to all the known substances of the chemical catalogue. Moreover, when any body is compounded of two simple substances and enters into combination with another body, the sum of the equivalents of the two elements will give the number, denoting the proportion in which it will so combine. Having endeavoured to convey a general idea of this universal law of chemical composition, it does not enter into our plan to pursue the subject further in this place: its full development will only be found in the complete body of chemical facts.

(§ 28.) The attraction of cohesion is opposed to the highest degree of chemical attraction in the same way as to the inferior degrees. Barilla or carbonate of soda is capable of acting strongly upon pounded flint, and produces, by its combination with it, the well-known substance, crown glass: but before the attraction of cohesion in the flint is diminished by pounding, the chemical affinity between them is not efficient.

(§ 29.) The minor degree of affinity by which solution is effected has also a strong influence over the power of composition. It acts chiefly by counteracting cohesion and repulsion, and thus bringing the particles of solids and aëriform fluids within the sphere of mutual action.

Sugar of lead and white vitriol, in their solid forms, have no action upon each other; but balance their powers of cohesion by dissolving them in water, and the double elective affinity is immediately at liberty to act in the way which we have pointed out (§ 26.)

(§ 30.) There is another circumstance, mechanical in its nature, and the influence of which is somewhat obscure, which sometimes interferes with *chemical composition;* that is, *quantity:* for, in comparing the attraction of two bodies for a third, a weaker affinity in one of the two is found to be compensated by increasing its quantity. If one part of common salt (which may be considered as composed of muriatic acid and soda) be mechanically mixed with half its weight of red lead (oxide of lead) and water, to the consistency of a thin paste, no decomposition of the salt will ensue: the soda has a stronger attraction for the acid than the oxide of lead. If, however, the weight of the red lead be increased to three or four times that of the salt, after standing some time, the strong taste of the soda will be perceptible; proving that the larger quantity of the oxide has the power of detaching a considerable portion of muriatic acid from the soda, notwithstanding the stronger affinity.

(§ 31.) The influence of temperature upon the highest degree of chemical attraction, is various: sometimes it favors its operation by counteracting the cohesion of solids; sometimes it opposes it by increasing the repulsion of aëriform fluids. An increase of heat frequently increases directly the energy of affinity, and determines combinations which would not otherwise take effect; and different degrees of temperature often produce opposite effects.

We have shewn that, by raising the temperature of quicksilver or mercury to nearly its boiling point, a combination is determined between it and oxygen, one of the mixed gases of the atmosphere: if this compound be more strongly heated still, it will be decomposed, and oxygen and the metal will be reproduced.

If a spirit lamp be supplied with ether instead of alcohol, it will inflame upon approaching to it a body in a state of inflammation; but if instead of a body of so high a degree of heat a coil of platina wire, heated to redness, be laid upon the wick, the ether will still be consumed, and the wire will continue to glow, but no flame will be produced. The products of these two species of combustion will be totally different, and each is determined by the degree of temperature at first communicated, and which is maintained without variation, by the heat evolved in each process.

On Chemical Decomposition.

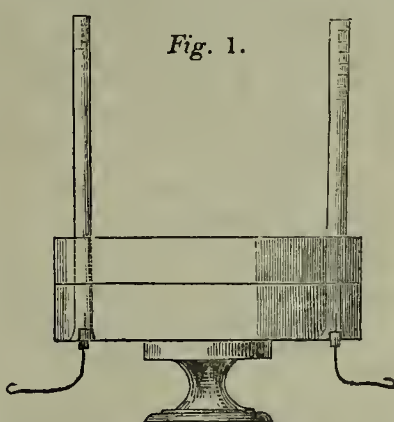
(§ 32.) We have seen how *chemical decomposition* may be effected by *elective affinity*, or the superior chemical attraction of one of two combined bodies for a third; and we have also seen that such decomposition may be brought about, in some cases, directly by the agency of heat. The agency of the voltaic pile is however the most general and effectual known in disengaging substances of different natures from their combinations with each other. Such a degree of repulsion may be communicated by means of electricity, to the ultimate particles of matter of unlike kinds, as entirely to counteract the strongest chemical attraction between them; and bodies which resist this powerful agent of decomposition are deemed *simple* or *elementary*. Of the *cause* of this repulsion we know no more than we do of the nature of attraction: its *effect* may be understood from the following experiment.

Place a few drops of a saturated solution of Glauber's salt (sulphate of soda) upon a piece of paper stained with the blue colour of litmus; and also a few drops of the same solution upon another piece stained with the yellow colour of turmeric: connect the two portions of the solution by a few filaments of moist cotton, and place the positive wire of an active voltaic pile in contact with that on the litmus paper, and the negative wire with that on the turmeric paper. In a short time the litmus paper will exhibit a bright red, and the turmeric paper a deep brown stain; the former being the indication of the presence of an acid, and the latter of an alkali. It will be recollected that we have described (§ 23) the composition of Glauber's salt from the action of affinity between sulphuric acid and carbonate of soda: by the decomposing action of the pile these are again disunited; and the soda appears at the negative and the sulphuric acid at the positive wire of the apparatus. This decomposition may be effected by a comparatively small power of electric action; and a pile of fifty pairs of copper and zinc plates suffice for the purpose.

If soda, one of the products of the last experiment, be subjected to the action of a more powerful pile, a further decomposition will take place; an elastic fluid, oxygen, will be given off at the positive wire, and a substance, endued with metallic lustre, will collect around the negative wire. This is the metal sodium: it is not susceptible of further decomposition, by the application of any power with which we are acquainted; and is, therefore, ranked with the simple substances. When the action of the pile is discontinued, it again rapidly attracts oxygen from the atmosphere, and is reconverted into soda. Sulphuric acid, the other product of the decomposition of the salt, may also be resolved into its elements by the same agency; in which case sulphur will collect at the negative pole, and oxygen be given off at the positive. These experiments will only succeed with a powerful voltaic apparatus, such as it is not easy to meet with.

We shall give another instance of decomposition, which may be produced by the moderate electric power previously referred to. Let the two wires of the voltaic pile, which for this purpose ought to be of platinum, be immersed in a vessel of pure water: the liquid will be decomposed; gaseous matter will be given off from each wire, but of very different properties, at the opposite extremities. It may be collected, by inverting glass tubes, closed at one end, and filled with water, over the wires, *fig.* 1. The elastic fluids will rise into the

Fig. 1.



tubes, and displace the water. The quantity collected over the negative wire will be double in volume to that collected over the positive wire. If a splinter of lighted wood be plunged into the first (which may be done by dextrously inverting the tube, and keeping the open end closed with a finger, till the flame be introduced), it will be instantly extinguished, but the gas itself will inflame at the surface. If into the second a splinter of wood, which, after being inflamed, has been extinguished, but still preserves

a glowing point, be immersed, it will be instantly rekindled, and burn with great brilliancy; but the gas itself will not take fire. To the former elastic fluid the name of hydrogen has been given; the latter is oxygen. These two bodies are the elements of water; and, not being capable of further decomposition, in the present state of our knowledge, are reckoned simple substances *.

(§ 33.) The peculiar mode of decomposition arising from *electrical repulsion* has afforded a basis for an artificial arrangement of the simple substances for the convenience of study; and by its means they are divided into two classes. The first consists of those elements which are attracted from their compounds with substances of the other class, by the positive pole of the voltaic pile; and as bodies in opposite states of electrical action attract one another, they may be called *electro negative* bodies.

The second comprises those elements which are attracted by the negative pole from similar combinations, and for the same reason may be distinguished as *electro positive* bodies. But this difference of electrical energies must be considered, in a great measure, as comparative; for in any compound of two bodies of the same class, for instance of the electro negative, one will be less electro negative than the other, and will consequently pass to the negative pole in the act of decomposition.

The elementary substances at present known do not amount to more than between fifty and sixty, and of this small number is all the beautiful variety of terrestrial matter composed! and what is still more wonderful! a very small proportion only of this small number enter into the composition of those objects of infinite diversity which are most familiar to our senses; and many of them are of such rare occurrence, and in the present state of our knowledge apparently of so little importance in the frame of creation, that the sole purpose of their formation would almost appear to have been a display of that infinite Power, by which all things were produced, for the admiration and gratification of the diligent inquirer, and a stimulus to his pursuits.

(§ 34.) There are four simple substances which exist in the gaseous state under the common circumstances of atmospheric temperature and pressure; these are oxygen, chlorine, hydrogen, and nitrogen. The first two belong to the *electro negative* class, and the last two to the *electro positive*.

Of these bodies, and of their combinations with each other, we shall proceed to give some account; but not in the order in which they stand above, as by departing from it in this instance, we shall have the advantage of treating, first, of the properties of some compounds which are every where presented to our observation; instead of commencing with others which are of rare occurrence, not easily produced, and not so perfectly understood. This will greatly facilitate the comprehension of the subject, and will amply compensate for any defect of arrangement.

Chapter II.

On the Gaseous Elements — Oxygen, Chlorine, Hydrogen, and Nitrogen, and their Combinations with each other.

*On Oxygen**.—8.

(§ 35.) Before we proceed to shew how oxygen gas may be obtained, it will be necessary to premise a few words upon the method of collecting and examining aëriform bodies. It is foreign to the design of this treatise, as we have before stated, to enter into the niceties of chemical operations, or to describe all the beautiful contrivances which ingenuity has introduced into chemical apparatus, for ensuring the utmost accuracy in delicate experiments. Although such inventions are highly useful, and even necessary, in carrying on original investigations, they are by no means required for obtaining that general idea of the laws of chemistry which every one ought to possess, for the proper understanding of the commonest concerns of life, and which may be sufficiently illustrated by every day occurrences, and easy experiments. In the way of apparatus, wine and beer glasses, of various sizes; apothecaries' phials; thin oil flasks, well cleaned; with glass and tin tubes of various dimensions; old gun barrels; tobacco pipes; an argand and a spirit lamp, with a common fire and bellows, offer almost inexhaustible resources to a

* For a further exposition of this subject, see the Treatise on Galvanism.

* Derived from two Greek words signifying "the formation of acids," as oxygen enters into the composition of a large majority of the acids, and was formerly supposed to be the general acidifying principle.

person endued with the faculty of contrivance; especially if he make himself master of the very easy art of sealing, bending, and enlarging a glass tube over a lamp.

For the collection of gases, sparingly soluble in water, a white earthenware foot-bath, or a small washing-tub, (*fig*. 2,) may be employed. In this a shelf should be fixed, or a metallic trivet stand, in such a way as that, when the bath is nearly filled with water, it may flow two or three inches above its surface. Glass jars, bell glasses, tubes, or bottles, may be filled with water by reclining them in the open part, and may afterwards be placed upon the shelf with their mouths downwards. A glass, or metallic tube,

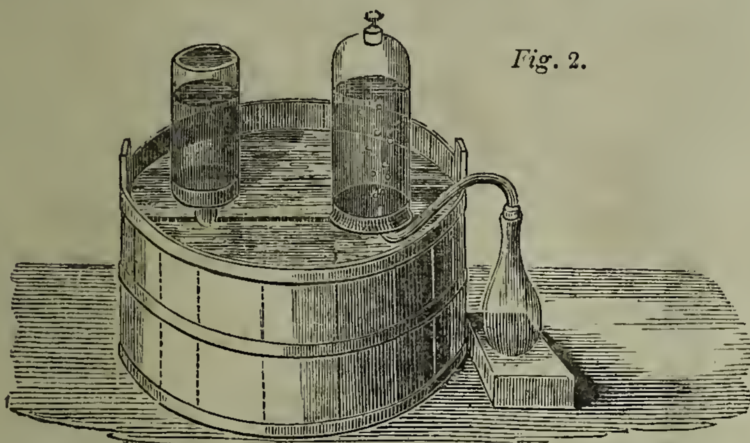


Fig. 2.

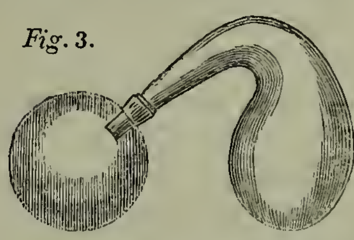
proceeding from the vessel containing the substances from which the aëriform fluid is emitted, may then be laid under the edge of the jar, which, for this purpose, is permitted to project a little over the shelf; the gas will then rise into it in bubbles, and gradually displace the water. A gas may also be readily transferred from one vessel to another, by carefully reclining the glass which contains it under the edge of another filled with water, and projecting over the shelf; and they may likewise be removed from the bath, and transported from one place to another, by placing them in shallow vessels or saucers, and surrounding them with about an inch of water. These operations are simple and easy; but no one should be disappointed in not succeeding in their performance, without some practice and perseverance.

(§ 36.) We have seen that when the metal quicksilver (or mercury) is submitted for a considerable time, in communication with the atmosphere, to the action of heat near its boiling point, it is converted into a brilliant red substance, which was formerly known to druggists by the name of *precipitate, per se*. In this operation the mercury increases its weight about 8 per cent.

The metal lead exposed to a strong heat with a large surface, and a free access of air, is also converted into a bright red substance, commonly known by the name of *minium*, or red lead.

Both these substances, when exposed to a red heat, give out the oxygen, which they had previously attracted from the air at a lower temperature; this operation may be performed in a retort, or glass tube, (*fig*. 3,) sealed at one end, a

Fig. 3.



little extended by blowing into it, and bent at an angle, the heat should be gradually applied. For the production of the gas, the small, open end of the retort should be placed under the edge of a vessel filled with water in the water-bath: in the figure it is represented as connected with a receiver for the purpose of distillation. Oxygen gas may, however, be better obtained for examination from a salt known by the name of Chlorate of Potash. This may be placed in a glass tube, with one end closed, and the other fitted with a cork, into which a smaller pipe is inserted, bent

at a right angle, (*fig.* 4,) and laid under the edge of a jar filled with water, on the shelf of the water-bath. When heat is applied, by means of a lamp, to this substance, it fuses, and gives out

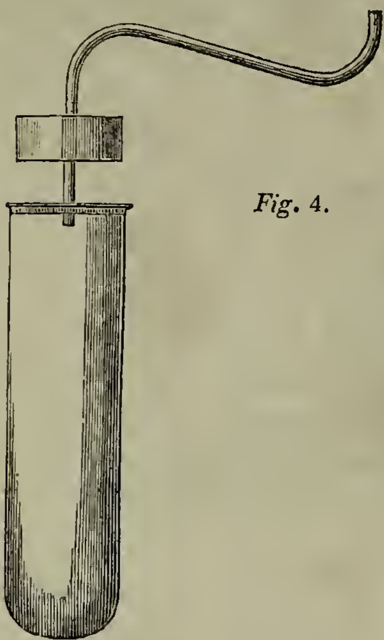


Fig. 4.

the gas in great purity. It may also be procured from saltpetre, or a substance known by the name of black oxide of manganese, strongly heated in a gun-barrel, with the touch-hole plugged up, and from which a small pipe of tin, or other substance, fitted to it, is laid under the jar. In collecting gases of any kind, the first portions should be always set aside as impure, as they are mingled with the common air which the apparatus necessarily contains.

Oxygen gas may also be collected in small quantities from growing vegetables, exposed to the solar light, or from the green matter which forms in stagnant pools, by immersing them in a bell glass filled with water.

(§ 37.) Oxygen gas is colourless, without smell or taste, and may be breathed with impunity for a considerable time; but in its pure state is ultimately found injurious to animal life. It is not dissolved by water, except in very minute quantities. It is rather heavier than atmospheric air; 100 cubic inches of the latter weighing 30.5 grains, and of the former about 3 grains more or 33.8.

(§ 38.) We will here explain, once for all, that in speaking of the weight of gases, we shall always suppose the barometer to stand at 30 inches, and the thermometer at 60°. Those who wish to know how they are affected by variations of temperature and pressure, and in what way corrections can be applied for such variations, must consult the treatise on *Gaseous Chemistry*, where these points will be explained, together with such minute details of manipulation as it does not enter into our present purpose to describe.

(§ 39.) All combustible bodies burn in oxygen with increased splendor. If the glass which contains it be furnished at the top with a stopper, it will be easy to prove this by introducing substances in different states of ignition. They may conveniently be attached to a wire passing through a cork which is made to replace the stopper when withdrawn. A small piece of wax taper, with its flame blown out, but its snuff still red hot, upon being let down into it, will be instantly rekindled, and burn with great brilliancy.

A piece of charcoal attached to the wire, and made red-hot, burns most vividly, throwing out beautiful sparks.

Fig. 5.

If the wire which passes through the cork be made to terminate in a small spoon, (*fig.* 5,) a small piece of sulphur or phosphorus may be placed in it and kindled; they will burn in the gas with a splendor which the eye cannot bear.

Twist some thin iron wire into a spiral form round a slender rod, which must then be withdrawn; let the end be dipped in melted sulphur and ignited; when let down into the gas, the iron will burn with a brilliant light, and scintillate like a firework.

If such a glass jar and stopper, as we have described, should not be at hand, these experiments may be performed in a common bottle, into the neck of which the cork and wire may be loosely inserted, and which it will not be found difficult, with the assistance of a small funnel, to fill with gas over the water-bath.

The above are all instances of intense chemical affinity, during the action of which light and heat are given off in abundance. During the various processes the oxygen will disappear, and the substances with which it combines will proportionally increase in weight. It is not difficult to prove these facts in

a general manner; but to perform the experiments with precision requires a complicated apparatus.

Coil up a known weight of iron wire, and place it in the bowl of a tobacco-pipe, the pipe of which is connected with a bladder filled with oxygen gas; heat the wire to redness in the fire, and then force through it a stream of the gas from the bladder. The iron-wire will burn; that is to say, it will combine with the oxygen, and from the intensity of the action light and heat will be emitted. When weighed, it will be found to be considerably heavier than before, and 100 grains will have increased to about 130.

Oxygen is electro-negative with regard to every other known body, and is attracted by the positive pole of the Voltaic pile from all its combinations, even with substances of its own class.

*On Hydrogen**.—1.

(§ 40.) If, into a bottle, containing filings or turnings of iron, or zinc, we pour sulphuric acid, diluted with six or seven times its weight of water, a strong action will take place, and a gas will be given off, which may be collected in the manner before described, by means of a bent tube, fitted to the mouth of the bottle with a cork. This is Hydrogen gas.

(§ 41.) It is colourless, and without taste; but, as commonly prepared, has a faint disagreeable smell; which, however, is supposed to depend upon some slight impurity. It is speedily fatal to animal life when taken into the lungs. It is not absorbed by water except in very minute quantities. It is lighter than atmospheric air; and, indeed, the lightest of all bodies which are known to possess weight; 100 cubic inches only weigh 2.1 grains. If a bladder be filled with it, and attached, by means of a stop-cock, to a tobacco pipe, upon dipping the bowl into a strong lather of soap, bubbles may be blown with it which will rise rapidly into the air; and it is upon this principle that it is used for filling air-balloons. It is inflammable, but it extinguishes flame.

Fill an inverted stoppered bottle with the gas, and close it with the stopper. Fix a small piece of wax-taper upon a wire, and ignite it; turn the bottle up, remove the stopper, and carefully introduce the taper. The gas will immediately inflame at the mouth of the bottle; but the flame of the taper immersed in the gas will be extinguished. Upon withdrawing the taper it may be rekindled as it passes through the flame of the gas, and again extinguished by returning it.

If a mixture of two parts of common air, and one of hydrogen, be made in a strong phial, capable of containing about four ounces of water, it will inflame upon presenting a candle to it, not silently, as in the last experiment, but suddenly, and with a loud explosion. The bottle should be wrapped round with a cloth to prevent accidents, in case it should burst in the experiment.

(§ 42.) Oxygen and Hydrogen gases may be *mixed* together in any proportions; and their disposition to become equally diffused in any given volumes, as with all gases, is so great, that even the vast difference in their specific gravities will not keep them separate.

Fit two glass phials with corks, into which a glass tube may be inserted ten or twelve inches long, and about one-twentieth of an inch bore. Fill one of the phials with oxygen, and the other with hydrogen. Place the former with its mouth upwards upon a table, and insert the cork with the tube; fit the cork into the latter, and fix it upon the other end of the tube with its mouth downwards. The hydrogen will descend and the oxygen ascend, notwithstanding the former is sixteen times lighter than the latter; and if they be permitted to remain two or three hours in the perpendicular position described, upon applying a light to either phial an explosion will take place.

(§ 43.) This explosion, which in the above experiment testifies the mixture of the two gases, is produced by the sudden exertion of that higher degree of affinity between the two gases, which gives rise to *composition*, and which is brought into action by the high temperature of flame. The compound in this instance is *water*.

The composition of water may be demonstrated by *synthesis* (which means the formation of any body from its elements), and by *analysis* (the resolution of a body into its component parts). Eight parts by weight of oxygen combine with one part of hydrogen to form water.

(§ 44.) Now, as hydrogen is the lightest known body in nature, and combines in the smallest proportion by weight, with

* From two Greek words, signifying "the formation of water," as it enters largely into the formation of that liquid.

the other simple substances, it is convenient to assume it as the standard of comparison for the combining proportions, or *equivalent numbers* of all other bodies; which, moreover, it is highly probable are simple multiples of its number. Hydrogen, therefore, thus standing at the head of the scale, and being represented by 1, the equivalent of oxygen will be 8, and that of water 9.

Oxygen, however, is sometimes assumed as the standard of comparison, and represented by the number 10, in which case the equivalent for hydrogen is 1.25; the result is of course the same, the proportion of 1.25 to 10 being the same as that of 1 to 8. The choice is one of convenience, and on this account we prefer the former.

We shall, in the course of this treatise, attach to the name of each substance, placed at the heads of the sections, its simple number upon this scale of equivalents; it is of the greatest importance to impress them strongly upon the memory, and they will thus be perpetually presented to the eye in a prominent manner. Where the body is compound, we shall also affix the proportions of the elements of which it is compound.

(§ 45.) The composition of elastic fluids developes a still more simple law of combination in this class of bodies, than that of *definite weights;* it is that of *definite volumes.* The union of gases is always effected in simple proportions of their volumes; and a volume of one gas combines with an equal volume, or twice or three times the volume of another gas, and in no intermediate proportion.

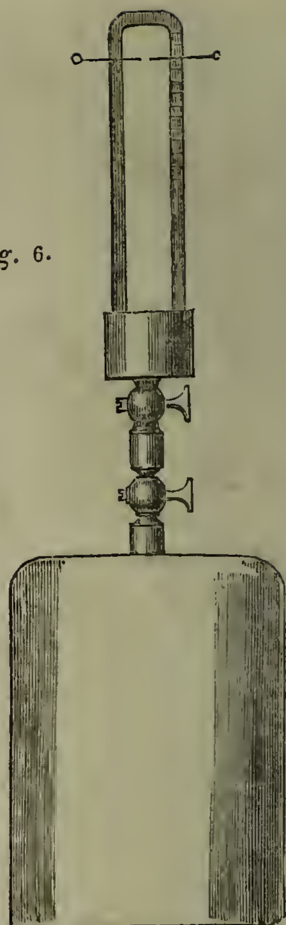
On Water.—9, (1 O. 8 + 1 H. 1).

(§ 46.) Oxygen and hydrogen combine in the proportion of one volume of the former, to two of the latter, to form water.

The experiment is one of some nicety, but may be performed in the following way.

Provide a very strong glass tube, (*fig.* 6,) closed at one end, and fitted at the other with a brass cap and stop-cock, strongly fixed with cement. Two small holes must be drilled in the upper part of this tube, into which two wires must be cemented, the points of which must nearly touch one another on the inside. Let a mixture of very pure oxygen and hydrogen gases be very accurately made, in the proportions named above, in a jar fitted with a stop cock, to which the

Fig. 6.



cock of the tube may be connected. Extract the air from the tube by means of an exhausting syringe, screw it on to the jar, and upon opening the cocks a portion of the mixture will rush in. Again exhaust the tube to secure the extraction of any remaining air. Replace it upon the jar, fill it again with the mixture, and carefully close the stop-cocks. Pass an electric spark through the wires, and the gases in the tube will explode. Allow the tube to cool, and upon opening the cocks a fresh portion of the gases will rush in, which will be equal to the first quantity, provided the mixture has been accurately made, and the common air perfectly extracted. This portion may be again inflamed, and the process continued, till a strong dew is seen upon the interior of the tube. This, upon examination, will be found to be pure water.

If the mixture be made in any other proportion than that of one of oxygen to two of hydrogen, the excess of either gas

will be left, for they will combine in no other. Those who have not the means of repeating this experiment, may convince themselves that the product of the combustion of hydrogen gas in oxygen is water, by burning a small stream of hydrogen from a bladder, under a bell-glass, with atmospheric air. As the combustion, i. e. the combination of oxygen and hydrogen, proceeds, water will condense upon the cold surface of the glass, and trickle down its sides.

(§ 47.) We have already adverted to the *analysis* of water by means of the voltaic pile (§ 32); it is in perfect accordance with its *synthesis*, and when both these processes agree in their results, the demonstration is the most perfect of which chemical philosophy is capable. The hydrogen given off at the negative pole is exactly the double in volume of the oxygen given off at the positive pole.

Water may also be decomposed, by means of heat and elective affinity, in the following way:—Take a gun-barrel, the breech of which has been removed, and fill it with iron-wire coiled up. Place it across a common chafing dish, and connect to one end of it a small glass retort containing some water; and to the other a bent tube, opening under the shelf of the water bath. Heat the barrel red hot, by means of charcoal, and apply a lamp under the retort. The steam of water, in passing over the red hot iron, will be decomposed, the oxygen will unite with the iron, and the hydrogen may be collected in the form of gas. This is the most economical way of making hydrogen in large quantities. Those who have an opportunity of visiting an ironfoundry, may see this process constantly going on; for when the melted metal is poured into the damp moulds, the water which they contain is decomposed, and the hydrogen which is given off is ignited; and generally, from its mixture with the air, produces a slight explosion.

If this experiment be made very carefully, by placing the iron-wire, previously weighed, in a glass, or very compact earthen tube, instead of the gun-barrel, the weight which the iron will have acquired, added to the weight of the volume of gas produced, will be found exactly to make up the weight of the water decomposed; and they will be to one another in the proportion of eight to one.

(§ 48.) It is needless to dwell upon the more obvious properties of the well-known fluid water, which is so abundantly diffused over the face of the earth. The purest state in which it is offered to us by nature, is as it descends from the clouds in the form of rain. It is colourless, inodorous, and insipid; and these negative characters confer upon it its greatest value. To enumerate its uses would be to transcribe a long chapter indeed from the book of nature, and is quite incompatible with our present limits. We must confine ourselves to marking a few of its characteristics in the three states in which it is presented to our observation, viz. as a liquid, a solid, or *ice*, and an aëriform fluid, or *steam*.

(§ 49.) It has been an object of the greatest importance to ascertain with precision the weight of a given volume of pure water, as it is the standard with which all other liquids and solids are compared; as the weights of aëriform fluids are with atmospheric air. Moreover, a recent act of parliament declares that the standard measure of capacity shall be the gallon, containing 10 lbs. avoirdupoise weight (7000 grains = 1 lb.) of distilled water, weighed in the air at the temperature of 62° of Fahrenheit's thermometer; the barometer being at 30 inches. The capacity of this gallon is 277.274 cubic inches.

From the most careful experiments, it appears that a cubic inch of water, at the temperature of 60°, weighs 252.52 grains, and consists of 28.06 grains of hydrogen, and 224.46 grains of oxygen. The volume of the former gas is 1325 cubic inches, and of the latter 662, making together 1987 cubic inches; so that the condensation is very nearly 2000 volumes into one.

(§ 50.) The effect of temperature upon liquid water is distinguished by a peculiarity of a very striking nature, and exhibits a departure from a general law of nature, for a purpose so obviously wise and beneficent, as to afford one of the strongest and most impressive of those endless proofs of design and omniscience in the frame of creation, which it is the most exalted pleasure of the chemist, no less than of the naturalist, to trace and admire.

All liquids, except water, contract in volume as they cool down to their points of congelation; but the point of greatest density in water is about 40°; its freezing point being 32°. As its temperature deviates from this point, either upwards

or downwards, its density diminishes; or, in other words, its volume increases. This peculiar law is of much greater consequence in the economy of nature, than might at first be supposed. The water which covers so large a portion of the surface of the globe, is one of the most efficient means of equalizing its temperature, and rendering those parts habitable, which would otherwise be bound up in perpetual frost, or scorched with intolerable heat. The cold air which rushes from the polar regions progressively abstracts the heat, from the great natural basins of water or lakes, till the whole mass is reduced to 40°; but at this point, by a wise providence, the refrigerating influence of the atmosphere becomes nearly null: for the superficial stratum, by further cooling, becomes specifically lighter; and instead of sinking to the bottom as before, and displacing the warmer water, it now remains at the surface, becomes converted into a cake of ice, and preserves the subjacent water from the further influence of the cold. If, like mercury, it continued to increase in density to its freezing point, the cold air would continue to rob the mass of water of its heat, till the whole sunk to 32°, when it would immediately set into a solid stratum of ice, and every living animal in it would perish: and in these latitudes, a deep lake so frozen would never again be liquefied.

(§ 51.) Water, at the moment that it assumes the solid form of ice, experiences a sudden expansion of still greater amount than the preceding. Its bulk is enlarged in the proportion of nine to eight; and in the act of freezing, if confined, it is capable of bursting the strongest vessels. The common experience in hard frosts of the cracking of water-pipes or of vessels in which water is suffered to freeze without room for this expansion, bears testimony to the fact. In consequence of its being specifically lighter, ice always swims upon the surface of water.

(§ 52.) A cubic inch of water at 40° is expanded by heat into 1694 inches, or nearly a cubic foot of steam, at the temperature of 212°; at which point its elasticity is equal to the mean elasticity of the atmosphere, or 30 inches of mercury: and when given off in this state it occasions the phenomena of boiling. The principal properties of steam may be exhibited in the following way. Procure a glass tube, *fig.* 7, about ¾ inch bore and 7 or 8 inches in length, closed at one end, and a little enlarged at the same extremity, by blowing into it when softened by heat. Wrap a piece of thin wash-leather round one end of a rod of wood 10 inches long, till it just fits into the tube and forms a piston, which will move freely in it. Pass the glass tube through a perforated cork, so as to form an exterior collar at its upper end. Stick a fork into this to form a handle, by which it may be held over the flame of a lamp. Put a little water into the bottom and heat it. When it boils briskly the air will be expelled by the steam, and the piston is then to be introduced a little way. Plunge the tube into cold water, and the steam will be instantly condensed, and the piston will be driven down by the pressure of the atmosphere upon the vacuum thus formed under it. Cause the water again to boil, by holding it over the flame, and the elastic force of the steam will drive the piston upwards; which motions may be alternately produced by repeatedly heating and cooling the water in the bulb of the tube. It is the production and sudden annihilation of this elastic force which is the source of the prodigious power of the steam-engine.

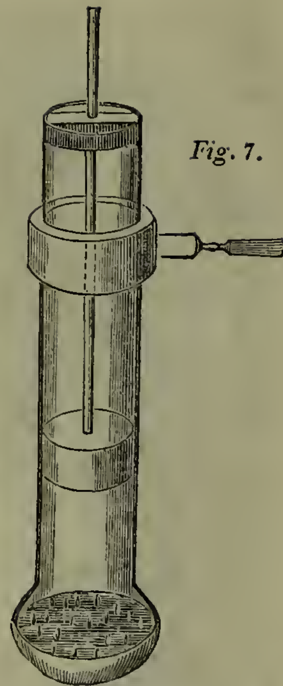


Fig. 7.

Steam is perfectly transparent and invisible, as may be observed when the water boils and the tube is filled with it, or as it at first issues from the spout of a tea kettle. It is only when it is beginning to be condensed that it puts on that cloudy appearance which many people suppose to be essential to it.

(§ 53.) But steam is not only formed from water at its boiling point, but rises slowly and quietly from it at all temperatures, even below the freezing point.

It is always found mixed with the permanent gases of the atmosphere, even in the driest weather; as may be seen by the dew which is deposited upon cold bodies, such as a glass of water fresh drawn from a well in summer. Its elasticity at the freezing point is equal to 0.200 inch of mercury, and its force increases in a geometrical progression for equal increments of temperature.

Oxygenized Water.—17.
(2 O. 16 + 1 H. 1).

(§ 54.) It was long supposed that there was only one compound of oxygen and hydrogen; but another has lately been discovered, in which hydrogen is united with a double proportion of oxygen, the numbers being, hydrogen 1, oxygen 16 or equal volumes of the two.

The only process at present known, by which it can be produced, is difficult, complicated, and expensive: so much so, that it is doubtful whether it has been ever tried in this country. We shall therefore pass it over, at present, and merely mention, that this oxygenized water is possessed of new and very remarkable properties. It is necessary to keep it surrounded by ice; for at a temperature of 58° it is decomposed, and oxygen gas is given off in abundance. It is liquid and colourless, like water; but produces upon the tongue a metallic taste. It attacks the skin with rapidity, bleaches it, and occasions a smarting sensation. By throwing some metals into it, in a state of fine division, such as silver or platinum, explosions are produced without effecting any change upon them, in a way which is not easily understood.

(§ 55.) In the systematic language of Chemistry (which has greatly conduced, by its simplicity and its ready adaptation to new facts, to the advancement of the science; and the principles of which we shall endeavour to explain as we proceed), the combinations of oxygen with other bodies, which are not acid, are termed *oxides*: and if more than one such compound with the same body should be known, they are distinguished as first, second, or third oxide, by the appellations, derived from the Greek numerals, of *prot*oxide, *deut*oxide, *trit*oxide, or the furthest degree of oxidation is denoted by the term *per*oxide. In this language, therefore, water is the *prot*oxide of hydrogen; and the compound to which we have just referred is the *deut*oxide, or *per*oxide of hydrogen.

On Nitrogen.—14.

(§ 56.) The next of the four gaseous simple substances, which we shall describe, is Nitrogen (or, as it has sometimes been named, Azote*). Like hydrogen, it belongs to the eleotro-positive class, being attracted by the negative pole of the Voltaic pile.

It constitutes four-fifths of the atmosphere of our globe, and may most readily be obtained for examination by removing the oxygen with which it is mixed, by the action of some superior affinity. The residue of atmospheric air, in which phosphorus has been suffered to burn out, after standing a little while over water, consists of tolerably pure nitrogen; or the oxygen may be absorbed by allowing the air to stand in a receiver over a mixture of equal weights of iron filings, and sulphur made into a paste with water.

(§ 57.) Nitrogen gas is distinguished by negative characters, rather than by any active properties.

It is colourless, inodorous, and tasteless; it is not absorbed by water, or only in very minute portions; no animal can live in it; it is not inflammable, and it instantly extinguishes all burning bodies introduced into it.

It is a little lighter than atmospheric air, 100 cubic inches weighing 29.7 grains.

Nitrogen with Oxygen.

(§ 58.) Nitrogen may be mixed with oxygen in any proportion; but four parts by volume of the former, and one of the latter, form a mixture resembling atmospheric air in all its properties. The atmosphere also contains a variable proportion of vapour of water as we have already stated (§ 53), and very minute portions of other matters which will be mentioned hereafter: its essential characters are, however, derived from these two ingredients.

The invariable uniformity of this mixture is one of the most surprising facts with which chemistry has made us acquainted. Air has been examined in the most accurate manner, which has been collected, by means of a balloon, from a height of nearly 22,000 feet; and at the level of the sea; from the heart of the most crowded districts of the most populous towns; and from the summit of Mont Blanc; from within the polar

* From a Greek expression, signifying "privation of life."

circle; and from the equator; and no difference has been discovered in its proportions. The active properties of atmospheric air are all referable to the oxygen which it contains, and are those of that body diluted. Without oxygen no animal could live—in pure oxygen they would live, if the expression may be allowed, too rapidly, as a candle would burn with too great intensity. All the vital functions would be increased to a morbid excess. Many experiments have been tried upon the subject, but no gas, or mixture of gases, has ever been discovered which can support life in the same uniform manner as the mixture which has been so admirably adapted to the purpose, and so wonderfully preserved from change. All the common processes of combustion are the result of the affinity of the oxygen of the atmosphere for the bodies which burn in it, and in all it is consumed; but notwithstanding the enormous consumption, from this and other causes, it is perpetually renewed, and its proportion maintained, by an adaptation of means to the end so nicely adjusted, as to form one of the greatest wonders where all is admirable.

(§ 59.) There are no known means of making nitrogen and oxygen combine directly in a more intimate manner; and this is probably one provision for the permanence and salubrity of the air we breathe; as such compounds otherwise obtained are all noxious, and most of them corrosive and poisonous. Indications of such a direct union have, indeed, been obtained by passing strong electric sparks through portions of common air, but it was effected with great labour and perseverance.

Five distinct compounds may, however, be produced by other means; and they admirably illustrate the change of properties conferred by composition in different, but multiple proportions. The first two belong to the class of oxides, not having any acid properties; and they may be called the protoxide and the deutoxide of nitrogen. The three last are acids.

(§ 60.) Now when a substance forms more than one acid combination with oxygen in different proportions, the chemical nomenclature distinguishes them as follows:—

The highest degree of oxygenation is marked by its name terminating in *ic*, as the nitr*ic* acid; that of the next degree is made to terminate in *ous*, as the nitr*ous* acid; and should there be an acid of a degree still lower, the Greek preposition *hypo* (under) is prefixed, to denote an under proportion of oxygen, as the *hypo*nitrous acid.

Protoxide of Nitrogen.—22 (1 N.14+1 O.8).

(§ 61.) The protoxide of nitrogen (or as it is sometimes called nitr*ous* oxide) is best obtained by fusing a salt called Nitrate of Ammonia in a retort over an argand lamp. This salt is not always to be obtained, but is very easily formed by dissolving Carbonate of Ammonia (of which the common smelling salts are made) in nitric acid (aquafortis) diluted with five or six parts of water. The solution is to be evaporated, till a drop of it, taken out upon a glass rod, concretes on cooling.

When the salt is liquefied, it should be cautiously kept simmering by a gentle heat; the gas is given off, and may be collected over water; but as it is absorbed by this fluid in a considerable proportion, the tube through which it passes into the jar should be conducted to its top, *fig.* 8, that it may not have to pass the whole column.

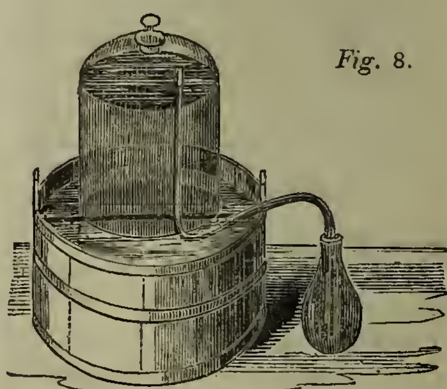


Fig. 8.

(§ 62.) The protoxide of nitrogen is a colourless, elastic fluid, considerably heavier than common air, 100 cubic inches weighing 46.5 grains. It has a sweetish taste, and faint agreeable smell. Water dissolves about its own bulk of this gas. Animals, when wholly confined in it, die very speedily: it may, however, be breathed for a short time with impunity; and it has been found to produce a most extraordinary excitement in the human frame. The experiment may be tried, by filling a clean bladder with it, and inhaling it repeatedly through a pipe attached to a stop-cock. Care

should be taken that the gas is very pure. The sensations which it produces have been variously described by different people, but all have agreed that they are very agreeable, and much resemble the exhilaration produced by spirituous liquors. It has mostly occasioned an irresistible propensity to laughter and muscular exertion, not followed by that depression and sense of lassitude which generally succeed excitement from fermented liquors.

This gas does not change the colour of blue vegetable infusions, and, therefore, is not acid.

Many substances, when introduced into it in a state of inflammation, burn with great splendour, from their superior affinity for the oxygen, with which they combine, setting nitrogen free. The glowing wick of an extinguished taper is immediately kindled by it into flame.

Iron-wire, and red-hot charcoal, burn in it, with nearly the same splendour as in oxygen gas, but for a shorter time.

Phosphorus introduced into it, in a state of active inflammation, burns with great violence, almost approaching to explosion.

When mixed with hydrogen, it will detonate either by the application of flame, or of an electric spark.

(§ 63.) Two volumes of the protoxide require two volumes of hydrogen for their complete decomposition, and the residue is two volumes of nitrogen. The experiment may be tried in the apparatus previously described for the detonation of mixtures of oxygen and hydrogen, *fig*. 6.

Now, as two volumes of hydrogen are equivalent to the saturation of one volume of oxygen, we infer that the protoxide of nitrogen is composed of two volumes of nitrogen and one of oxygen, condensed into two volumes; and the specific gravity of the gas confirms this influence, for the weight of

100 cubic inches of nitrogen is	29.7 gas	(§ 57)
and of 50 oxygen .	16.8	(§ 37)
making the weight of 100 cubic inches of protoxide - -	46-5	

as before stated from experiment.

(§ 64.) The equivalent number of nitrogen is also deduced from the same *data* for

$$16.8 : 29.7 :: 8 : 14,$$

that is to say, the number for oxygen being denoted by 8, that of nitrogen must be 14; these two numbers being in the same proportion (allowing for the unavoidable inaccuracies of delicate experiments) as 16.8 to 29.7, the combining weights in the above experiment.

This is an example of the mode of reasoning, by which the composition of a body may be deduced from the results of analysis; which, as the protoxide of nitrogen cannot be formed by the direct union of its elements, is the only means of ascertaining it in the instance before us. The method is unobjectionable, but the proof not so satisfactory as when we are able to confirm it by synthesis. When the two methods concur, the conclusion, which rests upon them, has all the certainty of a mathematical demonstration.

Deutoxide of Nitrogen.—30.
(1 N. 14 + 2 O. 16.)

(§ 65.) The deutoxide of nitrogen (or, as it is sometimes denominated, nitr*ic* oxide) may be obtained from the action of nitric acid (aquafortis) upon copper. The metal may be put into a retort, and the acid poured upon it, when a brisk effervescence will take place, and the gas may be collected in a jar in the water-bath.

(§ 66.) It is a permanent elastic fluid, very sparingly soluble in water, and does not, when pure, act upon blue vegetable colours. It is wholly irrespirable. The flame of most bodies, as of a taper or sulphur, is instantly extinguished, by being immersed in it; but it parts with its oxygen to charcoal and phosphorus, if introduced in a state of vivid inflammation, and they burn in it with increased energy. It does not explode, when mixed with hydrogen in any proportion; but it colours its flame green, if burnt with it in the common air.

It is but little heavier than atmospheric air, 100 cubic inches weighing 31.7 grains. When mixed with oxygen gas, deep red fumes are generated; and if the experiment be made over water, a great absorption will ensue; and when the gases are perfectly pure, and mixed in the proper proportions, they entirely disappear. The same appearance takes place with atmospheric air, and the diminution upon mixture is proportionate to the quantity of oxygen which it contains. From this property of condensing oxygen, and no other gas, it has been much used in *eudiometry*, or for measuring the purity of atmospheric air, which was formerly supposed to depend upon a varying proportion of that gas.

In this process an acid is formed, as

may be proved by the following experiment. Paste a slip of paper, stained with litmus, within a glass jar; and into the jar, filled with, and inverted over water, admit as much Deutoxide of Nitrogen, well washed by agitation with water, as will displace the water below the level of the paper. The blue colour will remain unchanged; but on admitting common air, or oxygen, it will be immediately reddened.

It may be decomposed by suffering it to stand over iron filings, which abstract a portion of its oxygen, and convert it into *prot*oxide of nitrogen.

(§ 67.) Its composition has been accurately ascertained by burning charcoal in it, which combines with the whole of its oxygen, amounting to half its volume, and leaves nitrogen to the amount of the other half. Hence we infer that it is composed of equal volumes of the two gases uncondensed; and that the volume of oxygen is exactly the double of that in the preceding compound. This result agrees exactly with its weight, for

	Grains.	
50 cubic inches of oxygen weigh . .	16.8	(§ 37.)
50 cubic inches of nitrogen weigh . . .	14.9	(§ 57.)
making together .	31.7	

the weight of 100 cubic inches of the deutoxide as before stated from experiment.

Its composition, therefore, upon the scale of equivalents is,

1 equivalent of nitrogen . .	14
2 ditto of oxygen . . .	16
	30

Hyponitrous Acid.—38.
(1 N. 14+3 O. 24)

(§ 68.) The next combination, in order, of nitrogen with oxygen, the hyponitrous acid, is rather hypothetical (conjectural), inasmuch as it never has been exhibited in a detached form.

For its production, a mixture of deutoxide of nitrogen and oxygen must be made over mercury, instead of water, upon the surface of which a little solution of potash must float. The proportions must be 4 volumes of the former, and 1 of the latter. They combine together under these circumstances, and form an acid which immediately unites with the potash, but which cannot afterwards be separated from it without undergoing decomposition. It will not be necessary to say more upon this compound, and we only notice it as forming a link between the last and the next compound. We have seen that 4 volumes of the deutoxide are composed of

2 volumes of nitrogen
2 volumes of oxygen,

and the additional volume makes 3 volumes of oxygen to 2 of nitrogen in the composition of hyponitrous acid, or in numbers,

1 proportion of nitrogen .	14
3 ditto of oxygen . .	24
	38

Nitrous Acid.—46. (1 N. 14+4 O. 32.)

(§ 69.) The next compound is the nitrous acid, which may also be produced by adding oxygen to the deutoxide of nitrogen. The experiment will not succeed over water or mercury, but may be conducted in a glass retort, fitted with a stop-cock, from which the air has been extracted by an exhausting syringe. In this way a mixture may be made of 2 measures of the deutoxide, and 1 measure of oxygen, which will be condensed into half their volume, and form a deep orange-coloured gas: 2 volumes of the deutoxide are composed, as we have seen,

1 volume of nitrogen, and
1 volume of oxygen,

and 1 volume of oxygen now added, form 2 volumes of oxygen to 1 of nitrogen in the composition of nitrous acid, or in numbers,

1 equivalent of nitrogen .	14
4 ditto of oxygen . .	32
equivalent of nitrous acid	46

(§ 70.) A taper will burn in this gas, and phosphorus most vividly. Charcoal also burns in it with a dull red light.

Water dissolves it, and acquires a green tint, which changes to blue, and finally to yellow, as more of the gas is absorbed. The solution is sour, reddens litmus paper, and stains animal substances yellow. It has been called liquid nitrous acid; but with regard to this solution, there is some ambiguity to which we shall hereafter again refer.

No practically useful application has been made of any of these compounds.

Nitric Acid.—54. (1 N. 14+5 O. 40.)

(§ 71.) We have already mentioned that by laboriously passing electric sparks, from a powerful machine, through a

mixture of oxygen and nitrogen, some indications are obtained of an union between the two gases: the product is a small quantity of nitric acid.

This acid may readily be produced by passing the deutoxide of nitrogen *very slowly* into oxygen gas, standing over water. By this operation, four volumes of the former combine with three of the latter; and the compound, therefore, must consist of 2 volumes nitrogen, and 5 volumes oxygen, or by weight of

1 equivalent of nitrogen .	14
5 ditto of oxygen . .	40
making the equivalent of nitric acid	54

The acid as it is formed is absorbed by the water, and it is very doubtful whether it can be exhibited in an insulated state.

(§ 72.) The liquid nitric acid is of very great importance in the arts, and is used in large quantities. It is procured, for commerce, by distilling nitre with strong sulphuric acid: the product is an intensely acid liquid, which, when pure, is colourless, and when most concentrated has a specific gravity of 1.5; that is to say, it is by half heavier than water. In this state it contains 25 per cent. of water; which is the least quantity with which it is known to exist, and is therefore a definite compound of

1 equivalent nitric acid . . .	54
2 ditto of water (9 × 2) . .	18
	72

which are in the same proportion to each other as 75 : 25. And we have before shewn (§ 44), in speaking of the union of oxygen with hydrogen, that the equivalent of water is 9.

In this state it is called *hydro*-nitric acid (from a Greek word, signifying water) to denote this combination. In entering into other compounds, it abandons the water and combines in the dry, or, as it is termed, the *anhydrous* state.

It may be *mixed* with water in any proportions beyond the 25 per cent.

(§ 73.) The nitric acid is a highly corrosive fluid, and acts as a powerful cautery when applied to the skin, which it stains of a permanent yellow. It is decomposed, with great violence, by most substances which have an affinity for oxygen; which element enters so largely into its composition. If it be brought into contact with hydrogen, at a high temperature, a violent detonation will be the consequence; but the experiment is dangerous, and should not be made without great caution. When poured upon warm, dry charcoal in powder, combustion ensues, with the emission of copious fumes of deutoxide of nitrogen. Spirits of turpentine may be inflamed by suddenly pouring nitric acid upon it: the acid should be poured out of a phial attached to a long stick, or there would be danger to the eyes of the operator

(§ 74.) In reviewing these various compounds of oxygen and nitrogen, the mind cannot but be impressed with the wonderful nature of that species of attraction which, by such apparently simple means, as mere variation of proportions and approximation of particles of two bodies, can confer such essentially different properties upon matter! In the atmosphere by which we are surrounded, we are presented with an active principle, essential to the existence of life, but injurious in its pure state, diluted by measure and weight, with an inert fluid to the exact proportion which is most beneficial to animal existence. It is perpetually consumed and perpetually renewed; but never exceeds or falls short of its determined quantity. This bland, tasteless, inodorous, invisible mixture, in which we are perpetually immersed, and upon the maintenance of which our existence depends, by the mere approximation of its particles, in a manner to us mysterious, is capable of being converted into a poisonous, corrosive, suffocating red vapour, which would instantly destroy all organized matter. By approximating in other proportions, an intoxicating deleterious atmosphere would be produced; or compounds with other properties, but all destructive of life. Such affinities, it is clear, exist; but are happily restrained by the Great Legislator who framed the laws of nature.

Nitrogen with Hydrogen.

Ammonia.—17. (1 N. 14 + 3 H. 3).

(§ 75.) We come now to examine the affinity between nitrogen and hydrogen. These two gases may be *mixed* in any proportions; but there are no means known of causing them to unite *directly* in a more intimate manner. Such a compound may, however, be obtained *indirectly*. There is a saline body, well known in the arts by the name of *sal-ammoniac*: if some of this salt be finely pounded, and mixed with an equal quantity of unslaked quick lime, in powder, and introduced into a tube or retort, upon the application of a gentle heat, it will give out an extremely pun-

gent smell, well known as arising from spirits of hartshorn. This proceeds from the evolution of a gas, which is rapidly absorbed by water, and therefore cannot be collected, as the gases we have hitherto treated of, over that liquid. It may, however, be obtained in jars filled with mercury, in a similar way to the water bath; and various forms of apparatus have been contrived to facilitate the operation in this and similar instances, and to economise the mercury, which is an expensive article. Its principal properties may, however, be exhibited by collecting it in a prepared bladder, made thin by scraping, and furnished with a stop-cock, which may be attached to the mouth of the retort containing the above mixture. It will become inflated as the gas is given off; and it may be preserved for a short time by closing the cock and detaching the glass. This elastic fluid is called ammonia.

(§ 76.) An animal plunged into it immediately dies, and the flame of burning bodies is extinguished by it. The flame of a taper becomes enlarged, with a kind of yellow halo before it goes out, shewing an inclination of the gas itself to burn; and if a small jet of it be introduced into a jar of oxygen, it may be inflamed—the product of the combustion being water and nitrogen.

It is very much lighter than common air, 100 cubic inches only weighing 18.05 grains.

It changes the blue colour of vegetables to green, and yellows to brown; but not permanently, for as the gas escapes the original colour returns.

(§ 77.) Ammonia may be resolved into nitrogen and hydrogen gases, by passing it through a red hot tube; and more rapidly, if the heated surface over which it is driven be increased by iron-wire coiled up in the tube. The experiment may be made in the apparatus before described, (§ 47,) by filling a bladder with the gas, expelling it through the heated tube by pressure, and receiving the nitrogen and hydrogen in a jar upon the water-bath. A mixture of ammonia and oxygen may be inflamed by the electric spark, just as a mixture of oxygen and hydrogen. The mere passing electric sparks through it also effects its decomposition. By this process its bulk is gradually enlarged, and when two or three hundred discharges have passed through a cubic inch of it, it will be found to have doubled its volume.

Two volumes of ammonia produce, by their decomposition, 4 volumes; consisting of 3 volumes of hydrogen, and 1 volume of nitrogen.

Now, 150 cubic inches of hydrogen weigh	. 3.15 grs.	(§ 41)
and 50 ditto nitrogen	. 14.9 grs.	(§ 57)
Together	18.05	

which, as 2 volumes are condensed into 1, will be the weight of 100 cubic inches of ammonia, and agrees with the direct experiment. Its constitution, therefore, by weight is—

One equivalent of nitrogen	. 14
Three ditto hydrogen	. . 3
and its equivalent	. . 17

(§ 78.) The solution of ammonia in water is commonly known by the name of liquid ammonia; but incorrectly, as the pure gas is capable of assuming the liquid form under high pressure, equal to that of 6½ atmospheres, or 195 inches of mercury.

The aqueous solution of ammonia, which is an article of great importance and extensive use, may be prepared by passing the gas, as it is formed, directly into water, which, at the temperature of 50°, will take up 670 times its volume; its bulk is thereby increased, and its specific gravity diminished: that of a saturated solution is .875, water being 1000.

The solution may be more conveniently prepared by the following process:—On 9 ounces of well-burnt lime pour half a pint of pure water; and when it has remained in a well-closed vessel about an hour, add 12 ounces of *sal ammoniac* in powder, and three pints and a half of boiling water. When the mixture has cooled, pour off the clear portion, and distil from a retort 20 fluid ounces. The specific gravity of this solution is .954.

It possesses the peculiar pungent smell, taste, and alkaline properties of the gas itself, and has the same action upon vegetable colours.

(§ 79.) We have thus arrived at the knowledge of two principal compounds of nitrogen, of the directly opposite qualities which characterize two great classes of bodies called *acids* and *alkalies*. The first, with 5 proportions of oxygen, constituting the nitric *acid*, intensely sour, corrosive, and turning the blue colour of vegetables red; the second, with 3 proportions of hydrogen, producing the volatile *alkali* or ammonia, hot, bitter. caustic, converting vegetable blues to green, and yellows to brown.

It will, we conceive, greatly facilitate

the comprehension of the subjects of affinity and definite proportion, if we stop to illustrate them, by considering the further combination of these two bodies together; although it does not enter into our general plan to examine the properties of bodies of this class, till we have completed the list of simple substances, and their binary compounds.

(§ 80.) By carefully dropping a solution of ammonia into diluted nitric acid, they will neutralize each other; and the exact point of saturation may be ascertained, by dipping into the solution, from time to time, small slips of paper stained with litmus and turmeric: when these colours are no longer affected, the neutralization is complete. The solution will now be neither acid, corrosive, alkaline, nor caustic; but its taste will be saline and bitter. If the liquor be carefully evaporated at a temperature not exceeding 100°, it will shoot, on cooling, into prismatic crystals. The salt so produced is called nitrate of ammonia, and is a definite compound of nitric acid, ammonia, and water. Its proportions have been very carefully ascertained to be in 100 parts,

acid	. 67.63
alkali	. 21.14
water	. 11.23
	100

which are in proportion to each other as

1 equivalent	nitric acid	. 54	(§ 71.)
1 ditto	ammonia	. 17	(§ 77.)
1 ditto	water	. 9	(§ 44.)

the numbers for which were formerly obtained from the direct combination of the elements of each.

(§ 81.) Water thus combined with a salt is called its *water of crystallization:* it is essential to its existence in the crystalline state, but may be generally expelled by heat, leaving the *anhydrous* salt in an amorphous (or shapeless) state, but with all its properties unchanged.

This it is difficult to effect in the present instance, as the salt is very easily decomposed by heat, and at a temperature of 600 explodes, being wholly resolved into its elements.

(§ 82.) The results of its decomposition at a lower temperature we have already shewn (§ 61), in describing the formation of the protoxide of nitrogen; and this process may now be understood.

Nitrate of ammonia, which is melted at a gentle heat, is composed of

1 equivalent nitric acid, 54 $\begin{cases}\text{1 equ. nitrogen, 14}\\ \text{5 do. oxygen, 40}\end{cases}$

1 equivalent ammonia, 17 $\begin{cases}\text{1 equ. nitrogen, 14}\\ \text{3 do. hydrogen, 3}\end{cases}$

or, in other words, the salt is composed of

2 equivalents	nitrogen . . .	28
3 do.	hydrogen . . .	3
5 do.	oxygen . . .	40

In this decomposition the 3 proportions of hydrogen take 3 of oxygen, and form water; and the remaining 2 proportions of oxygen combine with the 2 of nitrogen, and produce the protoxide of nitrogen: and these are the only products.

It is almost impossible for the least contemplative mind not to be struck with admiration at the harmonious simplicity of the laws upon which these transmutations depend: and the feeling of satisfaction which their development produces is part of that pure delight which, independently of more substantial advantages, rewards the diligent student of the works of nature.

On Chlorine*.—36.

(§ 83.) Chlorine, the last of the four aëriform elements which we have enumerated, belongs, with oxygen, to the electro-negative class; being evolved from all its compositions, except with oxygen, at the positive pole of the Voltaic pile. It may be obtained as follows:—Mix three parts of sea-salt finely pounded with one of peroxide of manganese—a substance well known in several of the arts by the name of black manganese; pour upon them in a retort two parts of sulphuric acid diluted with an equal weight of water: by the action of a gentle heat the gas will be given off. It may also be obtained by the action of muriatic acid upon the same oxide.

Cold water dissolves about twice its volume of chlorine; and mercury rapidly combines with it. It is best collected over warm water; and the waste from absorption may be diminished by leading the pipe, by which it is conducted, to the top of the jar; as was before recommended for the protoxide of nitrogen (§ 61.) It may be preserved in bottles with glass stoppers well greased, taking care that the water is wholly expelled from them.

(§ 84.) It possesses a yellowish green colour, an astringent taste, and a most suffocating smell; all of which

* From a Greek word, signifying "green," from its colour.

qualities are communicated to its aqueous solution. If received into the lungs, its action is extremely painful and injurious.

It is considerably heavier than common air: 100 cubic inches weigh 76.3 grains.

When a burning taper is introduced into it, it is quickly consumed with a dull red flame, which throws off a dense black smoke: phosphorus spontaneously ignites in it, and burns with a pale white flame; and several of the metals, in a finely-divided state, or in thin leaves, inflame: and in this way tin, copper, and zinc, exhibit a beautiful appearance.

Chlorine, mixed with the vapour of water, as it is usually obtained, assumes the liquid form at a temperature of 40°; and when surrounded with snow or pounded ice, concretes into a solid of a yellowish colour; which is deposited upon the sides of the receiver, like the effects of frost upon the surface of windows. If the gas be artificially dried by passing it over substances which abstract vapour, as a salt known by the name of muriate of lime, the most intense artificial cold produces no effect upon it. Strong compression, equal to four atmospheres, will, however, reduce it to the liquid form. It has no acid properties: it is not sour, and it does not change the blue colour of vegetables to red; but it destroys all animal and vegetable colours, and is a most important agent in the art of bleaching. This, however, it can only effect when water is present. If a piece of dry litmus paper be introduced into a jar of dry chlorine, it will suffer no change; but if previously wetted, the colour will speedily disappear. The colours of printed calico may readily be discharged by the same means.

Chlorine and Hydrogen.

Muriatic Acid.—37. (1 Ch. 36 + 1 H. 1.)

(§ 85.) Chlorine and hydrogen may be mixed together; and if carefully excluded from the light of day, will remain without change. If the mixture be made with equal volumes of the two, and exposed to light, they will gradually combine; the chlorine will lose its peculiar colour and smell, and a powerfully acid gas will result, without any change of volume. If the mixture be made in a stout phial, with a well-fitted stopper, secured by wrapping a cloth round the neck, and exposed to the direct rays of the sun, the combination will take place suddenly and with detonation. When the stopper is afterwards withdrawn under mercury, it will be found that no condensation has taken place; but if under water, it will instantly rush in and fill the phial—as the new compound is rapidly absorbed by that liquid. The mixture may also be exploded by flame, or the electric spark.

To this compound the name of muriatic acid has been given, and it is sometimes called hydrochloric acid. As the elements combine without condensation, its specific gravity must be the mean between those of its two ingredients.

	Grains.	
50 cubic inches of chlorine weigh . . .	38.10	(§ 84.)
50 ditto of hydrogen .	1.05	(§ 41.)
100 cubic inches of muriatic acid must therefore weigh . . .	39.15	

which agrees very nearly with direct experiment.

(§ 86.) Muriatic acid gas is best obtained by the action of strong sulphuric acid upon an equal weight of sea salt: it is given off in great purity, but must be collected over mercury.

The properties of such gases as are rapidly absorbed by water, may be examined without a regular mercurial apparatus, by means of a glass tube from half to three-quarters of an inch diameter, and from four to ten inches in length. It is closed above, but open at the lower extremity, and turned up (*fig.* 9). It may be filled with mercury, and is then to be supported with a saucer beneath it. The soluble gas may be produced in a small tube, or retort, drawn out, and fixed in such a way that the end may be introduced at the mouth so far as to allow the bubbles to pass into the tube, and the mercury to flow out into the saucer. When the metal has descended nearly to the bend, the operation should be stopped. Small portions of the gas so collected, may afterwards be examined, by placing the finger upon the aperture in contact with the mercury, so as to exclude all air. By inclining the tube, a bubble of the gas may be made to pass round the bend towards the finger; and upon replacing the tube in the perpendicular position, the larger quantity will still be in the upright part, and a

Fig. 9.

small quantity confined between the mercury and the finger, and quite unconnected with the former. This quantity may thus be conveniently experimented upon.

(§ 87.) Muriatic acid gas is colourless, of a very pungent smell, and intensely acid taste.

Its attraction for water is so great, that when a little of it escapes into the air, a white cloud is instantly formed by its combining with the atmospheric steam.

It extinguishes flame and is incombustible.

It instantly reddens blue vegetable colours.

It has been reduced to a liquid state by a pressure amounting to that of 40 atmospheres.

Water, at the temperature of 40°, will absorb of it about 480 times its volume, and thereby increases its bulk. The solution is commonly known by the name of muriatic acid, and is largely employed for chemical purposes. It may be prepared by passing the gas, produced as above, immediately into water; or by adding a sufficiency of water to the sulphuric acid in the first instance, and then distilling. The solution, when pure, is perfectly colourless, and it possesses all the acid properties and smell of the gas. Its specific gravity is greater than that of water, and when it amounts to 1.920 (water being considered 1.00) 100 parts contain 28.3 of real acid.

When muriatic acid is brought into contact with some oxides, they part with a portion of their oxygen, which forms water with its hydrogen, and chlorine is evolved: it is thus that the process previously described (§ 83) for obtaining chlorine with oxide of manganese may be explained.

The muriatic acid is the only known compound of chlorine with hydrogen.

Chlorine and Oxygen.

Protoxide of Chlorine.—44.

(1 C. 36+1 O. 8.)

(§ 88.) Chlorine and oxygen have but a feeble affinity for each other; but four distinct compounds of the two elements may be obtained by indirect means. They are never found in nature, and are subjects of instruction and curiosity rather than of use in the arts.

There is a salt to which we have before referred (§ 36), and the formation of which will be hereafter described, known by the name of *chlorate of potash:* when this salt is heated in a retort, with very weak muriatic acid, a gas may be collected over mercury: but as it is very apt to explode, the application of a naked flame to the retort should be avoided, and the heat is best applied by the medium of water. It differs very materially from chlorine.

(§ 89.) Its colour is much deeper, and is of a brighter yellow tint: its smell is intermediate between that of burnt sugar and chlorine.

It explodes by the application of a very gentle heat, not exceeding that of the hand, and is decomposed. Five volumes become expanded to 6, consisting of a mixture of chlorine and oxygen, in the proportions of 4 of the former to 2 of the latter; the oxygen in the compound being condensed into half its bulk. These proportions prove that it is a compound by weight of

1 equivalent of chlorine	. .	36
1 ditto oxygen	. .	8
Its number therefore is	.	44

It may be called the protoxide of chlorine.

Water dissolves eight or ten times its bulk of this gas, and takes an orange tint, but it does not act upon mercury.

It discharges all vegetable colours. Phosphorus upon being plunged into it takes fire, and causes it to explode.

It may be mixed with hydrogen, and exploded by the electric spark, and muriatic acid and water are the products.

Peroxide of Chlorine.—68.

(1 C. 36+4 O. 32.)

(§ 90.) Another combination of chlorine and oxygen may be obtained by operating upon *chlorate of potash* with sulphuric acid: 50 or 60 grains of the salt in powder may be mixed with strong sulphuric acid into a paste. The mixture will assume a bright orange colour. It may be placed in a small retort, or bent tube, which should be immersed in water, and gently heated, taking care to keep it under 212°, or the boiling point. A gas will be given off, which may be received over mercury, on which it has no action at common temperature.

(§ 91.) Its colour is also yellow, but brighter than that of the protoxide, and it is still more rapidly absorbed by water. The solution is deep yellow, and its taste not sour, but strongly astringent and disagreeable: it is decomposed by the action of light. The smell of this gas is peculiar and aromatic, and quite different

from that of chlorine. It explodes with great violence if heated to a temperature above 114°, and its volume is thereby increased by one-half. The products are chlorine and oxygen, in the proportions of 1 volume of chlorine to 2 of oxygen. It is, therefore, composed of

1 equivalent of chlorine	. . .	36
4 ditto oxygen	. . .	32
and its number is	. . . . .	68

It may be called the *peroxide* of chlorine. Phosphorus spontaneously ignites in it, and causes it to explode.

Chloric Acid.—76. (1 C. 36+5 O. 40.)

(§ 92.) The combination of chlorine with a further proportion of oxygen constitutes an acid, which may be obtained by decomposing a salt, which will be hereafter described, called *chlorate of barytes*, by elective affinity with dilute sulphuric acid. Great care must be taken not to use an excess of sulphuric acid; which may be dropped into a solution of the chlorate in water, as long as any white precipitate appears. The clear liquor which remains, after the process is complete, should be cleansed from the sediment; it consists of a solution of *chloric acid* in water. It may be concentrated by careful evaporation till it acquires an oily consistency.

(§ 93.) It is colourless; its taste acid and astringent; and its smell, when warmed, pungent. It reddens the colour of blue vegetables. The chloric and muriatic acids decompose each other, and, if mixed in proper proportions, they are each resolved into chlorine by the union of the oxygen and hydrogen, with which they are severally combined. Chloric acid is composed of

1 equivalent of chlorine	. . .	36
5 ditto oxygen	. . .	40
and its number is	. . . . .	76

Perchloric Acid.—100.
(1 C. 36+8 O. 64.)

(§ 94.) A compound of chlorine, with a further proportion of oxygen, has been discovered, but very little examined. It has been obtained in the state of an acid liquor, and has been called *perchloric acid.* It is supposed to be composed of

1 equivalent chlorine	. . . .	36
8 ditto oxygen	. . .	64
making its number	. . . .	100

Chlorine and Nitrogen.
Chloride of Nitrogen.—158.
(4 C. 144+1 N. 14.)

(§ 95.) Chlorine and nitrogen have but a very slight affinity for each other; but they may be obtained in union by passing chlorine through a solution of nitrate of ammonia at a temperature of about 90°. The chlorine is rapidly absorbed, and an oily film appears on the surface of the solution, which collects into yellowish drops, and sinks to the bottom of the vessel.

(§ 96.) This oily liquid is the most powerfully explosive compound known, and should not be experimented upon in quantities larger than a grain of mustard-seed; and even then it should be handled with extreme caution. Its specific gravity is 1.653, and it does not become solid at great degrees of artificial cold. At a temperature of about 200° it explodes; but the mere contact of some combustible substances, at ordinary temperatures, causes it to detonate. When a globule is thrown into olive oil, or turpentine, it explodes so violently as to shatter any glass vessel. The products of its decomposition are chlorine and nitrogen, and its composition has been inferred to be

1 equivalent nitrogen	. . .	14
4 ditto chlorine	. . .	144
making its number	. . . . .	158

(§ 97.) The name of chloride of nitrogen has been given to it: the chemical nomenclature conferring the appellation of *chloride* upon the combinations of chlorine with all bodies except oxygen, which have not acid properties: and as the analogous compounds of oxygen, when in more than one proportion, are distinguished by prefixing the Greek numerals, so the *chlorides* of different proportions are called *proto*-chloride, *deuto*-chloride, &c.

Chapter III.

On the Non-metallic Volatile Elements Bromine, Iodine, Sulphur, Phosphorus, and Selenium; and their Binary Compounds.

(§ 98.) The principal object of all arrangement in science is to assist the memory in acquiring and recalling a knowledge of the phenomena of nature; and that arrangement is best which most completely fulfils this primary design. With this view we have already

divided the undecompounded substances into two classes, viz. the electro-negative and the electro-positive; but, for further convenience, these it is necessary again to subdivide; especially as the first class contains only four known and one hypothetical (conjectural) body, the existence of which requires to be established by further proof. We have, therefore, formed one groupe of those elements which always assume the gaseous form under the common circumstances of atmospheric temperature and pressure. Of these, two belong to the electro-negative and two to the electro-positive class, and their properties we have examined, and their combinations with each other.

We shall now proceed to describe five other simple substances: the first of which assumes, at common atmospheric temperature, the form of a liquid, and the others of solids; but all agree in being *volatile*, or in rising in vapour by the application of a moderate degree of heat: they are all, likewise, non-conductors of electricity, and bad conductors of heat. These have been called bromine, iodine, sulphur, phosphorus, and selenium. The first two are evolved from their respective compounds (except with oxygen and chlorine) at the positive pole of the voltaic pile; and with oxygen and chlorine, and that other substance whose existence, as we have said, has been rather inferred from analogy than proved, complete the number of the electro-negative elements.

*Bromine.**—75.

(§ 99.) One of the sources of the greatest discouragement to those who take but a hasty view of the science of chemistry, and a cursory glance at chemical systems, is the number of new substances and unusual names with which they are perplexed at the first outset of their inquiries. The forms of matter with which they are first presented, are not those with which they are most familiar; and as they do not at once see the practical application of the knowledge thus submitted to them, they are apt impatiently to give up the pursuit. The fact undoubtedly is, that a knowledge of these elementary substances, very few of which are presented to us in nature in their simple state, or even in their binary combinations, and a considerable number of which are the fruits of modern research, constitutes the foundation of the science. The chemical compounds with which we are surrounded, and particularly the products of organization, are of a very intricate nature, and a knowledge of their constitution is most easily obtained by studying the properties of the elements, and ascending by the more simple combinations to the most complex. A large proportion, however, of the elementary substances are, as we have before mentioned, of very rare occurrence, even in a state of composition; and we would guard any one from the error of supposing that, because he may not have an opportunity of examining these scarce substances, a serious obstacle is thrown in the way of his advancement; for we again affirm, that such a sound practical knowledge of the science, as every one ought to acquire, may be attained by a well-directed study of the commoner elementary principles.

Bromine, as well as the next object of our investigation *Iodine*, have only been very lately discovered; and they belong to that class of substances, with whose use in the economy of nature we are at present totally unacquainted, and which have not yet been applied to any practical purpose: nevertheless, they are objects of the greatest interest to the chemist; and the study of their properties is particularly instructive, on account of the analogy which subsists between them and chlorine.

(§ 100.) Bromine has been obtained in very small quantities from sea-water and the ashes of sea-weeds.

If to a lixivium (washings) of the latter, or to the residual liquor of salt-pans, in which sea-water has been evaporated for the purpose of obtaining common salt, a solution of chlorine in water be added, a deep yellow colour and a peculiar odour will be produced. By distillation and passing the vapour over a salt, called muriate of lime, which detains the watery part, a few drops may be obtained of a red colour, very volatile and filling the receiver with vapours like those of nitrous acid: or, after passing chlorine into the above-named lixivia, they may be shaken up with some ether, which will dissolve the bromine; from which it will acquire a hyacinth tint, and float upon the surface. Upon agitating this solution with caustic potash, it immediately yields up the bromine to it; and the process may be repeated with the same ether: and

* From a Greek word, signifying "a strong disagreeable odour."

thus by alternately using the ether and potash, the new substance may be separated from a large portion of water. The bromine is extracted from the potash, by treating it with sulphuric acid, diluted with half its weight of water, and oxide of manganese; in an analogous way to that by which chlorine is obtained from sea salt.—(§ 83.) It is given off by distillation in red vapours, which condense into blackish red drops in the receiver, which should be kept cool.

(§ 101.) Bromine is a fluid of a hyacinth-red colour, when viewed by light transmitted through thin strata, At a temperature a few degrees below 0° it suddenly congeals and is very brittle. Its odour is extremely disagreeable and intense; its taste unpleasant and very powerful. It corrodes the skin and colours it yellow, but not permanently; it is very poisonous; its specific gravity is nearly 3; it is very volatile; gives off red vapours at common temperatures, and boils at 116°.5.

A taper will not burn in its vapour, but it alters the tint of the flame in air.

It is soluble in water, alcohol, and particularly in ether.

It does not redden, but destroys the colour of litmus, and even of indigo.

Bromine and Oxygen

Bromic Acid.—115. (1 B. 75 + 5 O. 40.)

(§ 102.) Bromine may be obtained in union with oxygen, in the form of an acid, by adding sulphuric acid to a solution of a salt, which will be hereafter described, called Bromate of Barytes, as as long as any precipitate is produced.

Bromic acid in solution has scarcely any odour, but possesses an acid taste and reddens, and gradually destroys the blue colour of litmus. It is probably a compound of

1 equivalent of bromine . .	75
5 ditto of oxygen	40
and its number . . .	115

It is therefore similar in its nature to the chloric and nitric acids.

Bromine and Hydrogen.

Hydro-bromic Acid.—76.
(1 B. 75 + 1 H. 1.)

(§ 103.) Hydrogen mixed with the vapour of bromine, and exposed to the light of the sun, undergoes no change; but on introducing a lighted candle, or a red-hot iron into the mixture, combination ensues in the vicinity of the heated body, but not with explosion. A colourless gas, possessed of acid properties, is thus generated, and it has been distinguished by the name of hydro-bromic acid.

It is rapidly absorbed by water, but may be preserved over mercury. It may be abundantly produced from a mixture of bromine and phosphorus, slightly moistened. It produces dense white vapours in the air from its combination with the steam, and it possesses a strong irritating odour. The solution in water is colourless, and possesses the principal properties of the gas.

The hydro-bromic acid is decomposed by chlorine, which combines with its hydrogen, forming muriatic acid, and the bromine is set free.

The decomposition of hydro-bromic acid, by substances which combine with its bromine, affords half the volume of pure hydrogen. Hence its composition is

1 equivalent of bromine . .	75
1 ditto of hydrogen	1
and its equivalent . .	76

It is therefore analogous in its composition to muriatic acid.

Bromine and Chlorine.

Chloride of Bromine.

(§ 104.) By passing chlorine through bromine, and condensing the vapours which arise at a low temperature, a reddish-yellow fluid may be obtained with a very penetrating odour and disagreeable taste. It is very fluid and volatile. Metals in a finely-divided state take fire in its vapour. The solution of this compound in water has strong bleaching powers.

Iodine*.—124.

(§ 105.) Iodine is another undecompounded substance, which has lately been extracted from the ashes of sea weeds, or the substance called *kelp*, which is largely produced on the western coasts of Scotland, and used for making soap. Its discovery preceded that of bromine, and, like it, its properties bear a strong analogy to those of chlorine. It is a very remarkable fact, although no useful inference has yet been drawn from the remark, that the three most electro-negative bodies, next to oxygen,

* From a Greek word signifying "Violet-coloured."

connected as they likewise are by common properties, exist almost exclusively in the ocean and its immediate productions.

The soluble part of *kelp*, or the ashes of sea-weeds dissolved in water, afford upon evaporation a salt called carbonate of soda; and after its extraction, an uncrystallizable residue remains. When sulphuric acid is poured upon this, in a retort furnished with a receiver, beautiful violet vapours make their appearance, which are condensed in crystalline plates of the colour and lustre of plumbago (commonly known as black lead). These crystals may be collected and dried between folds of blotting-paper. The addition of a small quantity of oxide of manganese facilitates the process of extraction

(§ 106.) Iodine, thus obtained, is a solid, at the ordinary temperature of the atmosphere, in the shape of scales or plates of regular forms. Its colour is dark-grey; and it possesses a metallic lustre. It is soft and friable, and may easily be rubbed to a fine powder. Its taste is hot and acrid, but it is very sparingly soluble in water. It is poisonous in large doses, but has been used in medicine. At 60° of Fahrenheit, it is nearly five times as heavy as water. It produces a yellow stain upon the skin, which speedily evaporates. It fuses at 225°, and assumes the elastic form, under the pressure of the atmosphere, at about 350°. In this state, when it is of a beautiful purple colour, it is 124 times heavier than hydrogen; and as it combines with that element in equal volumes, this number represents the weight of its combining proportion, or equivalent.

It has the property of forming an insoluble compound with starch, of a beautiful blue colour; and its presence may thus be detected in very minute proportions.

Iodine and Oxygen.

Iodic Acid.—164. (1 I. 124+5 O. 40.)

(§ 107.) Iodine is not altered by being heated in oxygen gas; but when it is exposed to protoxide of chlorine (§ 88), which holds this element by a very slight attraction, there is an immediate action; its colour changes to a bright orange, and a liquid is formed. By the application of a gentle heat, an orange compound of iodine and chlorine is evaporated, and a compound of iodine and oxygen remains.

(§ 108.) It is a white semi-transparent solid, without smell, but with a strong astringent, sour taste. It may be called iodic acid.

It is decomposed by heat, and the sole products are iodine and oxygen: 13 grains afford 9.25 cubic inches of the latter gas, or by weight 3.15 grains. Hence it is composed of

1 equivalent of iodine	.	124
5 ditto of oxygen	. .	40
and its number is	.	164

Its composition is therefore analogous to that of chloric acid. It is soluble in water, and its solution first reddens, and then destroys, blue vegetable colours.

Iodic acid, when mixed with charcoal, sugar, sulphur, and other combustible bodies, detonates upon the application of heat. The solution corrodes all metals, and even acts upon gold and platinum.

Iodine and Chlorine.

(§ 109.) Iodine absorbs chlorine, and forms with it an acid solid compound, whose nature is not yet perfectly understood.

Iodine and Hydrogen.

Hydriodic Acid.—125. (1 I. 124+1 H. 1.)

(§ 110.) When iodine is heated in hydrogen gas, an expansion of volume takes place; an acid gas is formed which is rapidly absorbed by water, and is acted upon by mercury so readily, that it cannot be long preserved over that metal.

The same gaseous compound is produced in abundance by the action of moistened iodine and phosphorus on each other. The oxygen of the water combines with the phosphorus, and the hydrogen with the iodine. The mixture may be distilled in a retort, and the gas received into a vessel filled with common air, which, by a proper arrangement, it will expel by its superior gravity. It has been called hydriodic acid.

(§ 111.) The gas is colourless; has a very sour taste, and pungent odour, and reddens blue vegetable colours, without ultimately bleaching them.

It is decomposed by mercury, which unites with the iodine, and leaves half the original volume of pure hydrogen; it is therefore a compound of equal volumes of iodine, in elastic state, and hydrogen.

	Grains,
Now 50 cubic inches of iodine have been found to weigh .	131.3
50 ditto of hydrogen . .	1.05
which would make the weight of 100 cubic inches of hydriodic acid . . .	132.35

and this agrees very nearly with direct experiment. Its composition by weight is

1 equivalent of iodine .	124
1 ditto hydrogen . .	1
and its number . .	125

The solution of hydriodic acid in water is fuming, and, when saturated, has a density of 1.7. It does not act upon mercury, although in the gaseous state it attacks it so powerfully. Chlorine takes the hydrogen from this compound; muriatic acid is formed, and iodine liberated.

Iodine and Nitrogen.

Iodide of Nitrogen.

(§ 112.) Iodine and nitrogen cannot be made to unite directly: but if iodine be kept in a solution of ammonia in water, the latter is decomposed; its hydrogen unites with part of the iodine, and its nitrogen with another part. The latter compound is precipitated in the form of a brownish black substance, which is the iodide of nitrogen.

(§ 113.) Like the chloride of the same element (§ 95), it is highly explosive. It detonates violently, as soon as it is dry; and the slightest pressure produces the same effect even when moist. It is supposed to consist of

3 equivalents of iodine .	372
1 ditto of nitrogen . .	14
	386

But all attempts to collect the products of its detonation with accuracy have failed.

Iodine and Bromine.

(§ 114.) Iodine appears to form two compounds with bromine; the first is a solid, which, when heated, gives off reddish brown vapours; the second is formed by a further proportion of iodine, and is a dark-coloured liquid. Their properties have not been minutely examined.

It is a curious fact, that chlorine takes hydrogen from bromine, and bromine from iodine; but the affinities of these three bodies for oxygen are in the inverse order.

Sulphur.—16.

(§ 115.) Sulphur is one of the few elements which occur in nature in their simple form. It is a well known mineral substance, found in large quantities in the neighbourhood of volcanoes; and, as an article of commerce, is chiefly brought from the Mediterranean. It is also extracted for use from some of its compounds. It is commonly met with in two forms—that of a compact, brittle solid; and that of a fine powder. It is of a light yellow colour; and when melted emits a peculiar odour. It is insoluble in water, and tasteless. It is about double the weight of water, its specific gravity being 1.98. It is readily melted and volatilized, and begins to evaporate at 170°, and to fuse at 105°. At 220° it becomes completely fluid; but possesses the peculiar property of solidifying at a higher degree, or at 350°, and of again melting by a reduction of temperature. It sublimes (this term is used to denote the evaporation of a solid) at 600°; and condenses into the form of a powder, or, as it is termed, of *flowers*. When poured into water, in the state of complete fusion, it becomes of the consistency of wax, and assumes a red colour: it may then be used for taking impressions from engraved stones, and hardens upon cooling.

Sulphur is completely soluble in boiling oil of turpentine, and in alcohol, when the two substances are brought in contact in the state of vapour. It is inflammable; that is to say, it combines, when ignited, with the oxygen of the atmosphere with the evolution of light and heat. It burns with a faint blue light, at a temperature of about 180° or 190°; and the evolution of heat is so small, that it may be burned out of gunpowder, of which it is one of the principle ingredients, without inflaming it. At a temperature of 300°, however, its combustion is more rapid.

Sulphur and Oxygen.

Sulphurous Acid.—32.
(1 S. 16 + 2 O. 16).

(§ 116.) When sulphur is burned in dry oxygen-gas, there is no increase in volume; but at common temperature and pressure, a colourless transparent gas is formed, which is distinguished from all other elastic fluids, by a suffo-

cating pungent odour, well known as the smell of burning brimstone. It may be obtained by the action of sulphuric acid upon mercury, in a state of great purity. The mixture may be put into a retort and heated, but the gas must be received over mercury.

It is called sulphurous acid gas.

(§ 117.) It extinguishes all burning bodies, when immersed in it, and cannot itself be burned. It is instantly fatal to animal life. It assumes the liquid form under a pressure not exceeding that of two atmospheres; or at the degree of cold produced by a mixture of snow, or pounded ice, and salt.

It first reddens blue vegetable colours, and then destroys them; and its bleaching powers are very considerable. The vapours of burning sulphur are much used in whitening silk and straw-work.

One hundred cubic inches of sulphurous acid weigh 67.5: which is exactly double the weight of an equal quantity of oxygen; so that the weights of sulphur and oxygen, in the compound, are equal; and, as there is reason to suppose, from data which will be hereafter specified, that it is composed of two equivalents of oxygen and one of sulphur, the number of the latter must be 16.

Water at 60° dissolves about 33 times its bulk of sulphurous acid; and the solution possesses its peculiar odour and taste, which is astringent. It cannot, however, be preserved any length of time without change.

Sulphuric Acid.—40.
(1 S. 16+3 O. 24).

(§ 118.) A MIXTURE of sulphurous acid and oxygen gas may be kept for any length of time without showing any further disposition to combine, provided they are quite dry. If water be present, the sulphurous acid will gradually unite, with a further proportion of oxygen, and the compound, which is sulphur*ic* acid, will be taken up by the water.

Sulphuric acid is an article of great importance, and is largely consumed in many manufactures; and there are several ways of procuring it for commerce.

By distilling, at a high heat, the salt called green vitriol (which, it will be hereafter seen, is a compound of sulphuric acid and protoxide of iron) a dense, oily, colourless liquid may be obtained; which emits white vapours on exposure to the air. If this liquid be again distilled, at a lower temperature, into a receiver surrounded with pounded ice or snow, a transparent, colourless vapour will pass over, which will condense into a white crystalline solid. It is tough and elastic; liquefies at a temperature of 66°, and boils at about 110° or 120°. It has a strong affinity for water, and immediately takes it from the atmosphere. This solid body, there is reason to suppose, is pure *an*hydrous sulphuric acid; but there are some doubts respecting its nature

The residue in the retort will be no longer fuming, and is the common oil of vitriol of commerce.

Hydro-sulphuric acid is also largely obtained by burning a mixture of about 8 parts of sulphur and 1 of nitre, in close leaden chambers, containing water. The fumes, as they rise, are dissolved; and the acid is procured in a concentrated state by evaporation of the solution. The hydro-sulphuric acid, or oil of vitriol, is a colourless, oily fluid, of a specific gravity, when most concentrated, of 1.85; at which density it contains about 81 per cent. of real acid. It boils at 620°, and freezes at 15°. It rapidly absorbs moisture from the air, and may be mixed with water in any proportion above that just stated.

(§ 119.) It is acrid, caustic, and intensely sour. It decomposes animal and vegetable substances rapidly; probably from its great affinity for water, which is an essential ingredient of their composition, and charcoal is produced. It often derives a brown tinge from small particles of this nature falling into it. It reddens blue vegetable colours, even when very largely diluted. When sulphuric acid is passed through a porcelain or platinum tube, heated to redness, it is decomposed, and two measures of sulphurous acid to one of oxygen are obtained. Its composition is therefore,

1 equivalent of sulphur .	16
3 ditto of oxygen . . .	24
	—
and the number of the anhydrous acid is	40
	—

If we add to these proportions 1 equivalent of water, we shall have for the composition of the hydro-sulphuric acid,

1 equivalent of sulphur .	16
3 ditto oxygen . . .	24
1 ditto water . . .	9
	—
and its number	49
	—

in which the water is in the same pro-

portion, 19 per cent., as in the acid of the specific gravity 1.85.

Hypo-Sulphurous Acid.—24.
(1 S. 16+1 O. 8.)

(§ 120.) When iron filings are digested in a solution of sulphurous acid, they are dissolved without effervescence; the iron takes half the oxygen from the sulphur, and an acid is formed with the other half, which combines and forms a salt with the oxide of iron so produced.

This acid has been called the *hypo*-sulphurous, upon the principle of nomenclature before explained (§ 60.) It cannot be exhibited in a separate state; for at the moment of quitting the base with which it is united, it is resolved into sulphurous acid and sulphur. It is a compound of

1 equivalent of sulphur .	16
1 ditto of oxygen . . .	8
and its number is . . .	24

Hypo-Sulphuric Acid.—72.
(2 S. 32+5 O. 40.)

(§ 121.) By passing sulphurous acid through water, in which finely-pounded peroxide of manganese is suspended by agitation, the peroxide yields part of its oxygen to the acid, and converts one portion into sulphuric acid, and another into a peculiar acid, which has been called the *hypo*-sulphur*ic*. The process for exhibiting the latter, in a separate form, is complicated, and we shall for the present postpone its consideration.

It is obtained in a liquid form, it reddens litmus paper, but has no smell, by which it is distinguished from sulphurous acid; and it forms soluble salts with oxide of lead, and other substances, whose combinations with sulphuric acid are insoluble.

The results of its analysis shew it to be a compound of

2 equivalents of sulphur .	32
5 ditto of oxygen . . .	40
and its number is . . .	72

Sulphur and Hydrogen.

Sulphuretted Hydrogen.—17.
(1 S. 16+1 H. 1.)

(§ 122.) By repeatedly subliming sulphur in hydrogen gas, a combination between the two elements takes place, without change of volume; and a gas is formed, to which the name of sulphuretted hydrogen has been given. It may be produced in abundance, by acting upon sulphuret of iron (which may be formed by melting together sulphur and iron filings) with sulphuric acid. It is quickly absorbed by water, but may be collected in glass bottles filled with that liquid, and provided with glass-stoppers, which must be inserted the moment they are filled with the gas.

(§ 123.) It is colourless and transparent. Its smell is very offensive, and resembling that of putrifying eggs, or the washings of a foul gun-barrel; its taste is acid.

It is highly poisonous, and a horse has been known to perish in an atmosphere which contained no more than 1-250th part of it.

It is inflammable; and, like hydrogen, burns either silently, or with explosion, according to the circumstances of its mixture with oxygen. It instantly extinguishes all burning bodies.

It tarnishes silver, gold, and mercury, and blackens white paint made with preparations of lead. Its solution in water acquires the taste and peculiar smell of the gas, and reddens blue vegetable colours. Some mineral waters, as those of Harrogate, are impregnated with this gas. Two measures of sulphuretted hydrogen require three of oxygen for their complete decomposition, one measure of which saturates the two of hydrogen, and the other two the sulphur; water and sulphurous acid are the products.

Now, 100 cubic inches of hydrogen weigh 2.11 grains, and 100 cubic inches of sulphuretted hydrogen 36 grains; and as the sulphur is taken up by the hydrogen without change of bulk, if we deduct the weight of the latter, the remainder 33.89 will be the weight of the sulphur, and 2.11 : 33.89 :: 1 : 16, which makes the equivalent of sulphur, as we before stated (§ 117) 16.

It follows also that sulphuretted hydrogen is composed of

1 equivalent of sulphur .	16
1 ditto hydrogen	1
and that its number is .	17

Bisulphuretted Hydrogen.—33.
(2 S. 32 + 1 H. 1.)

(§ 124.) A SECOND combination of sulphur with hydrogen is known, of which the proportion of sulphur is double that of the last compound. It may be produced as follows:—Boil together a strong solution of potash with flowers of sulphur, and gradually drop the product into muriatic acid; a small quantity of sulphuretted hydrogen will be given off, and an oil-like, adhesive, brown fluid, the *bisulphuretted hydrogen*, will fall to the bottom of the vessel: a large quantity of sulphur will, at the same time, be precipitated.

(§ 125.) Its smell and taste greatly resemble those of sulphuretted hydrogen: it is inflammable, and gives off fumes of sulphurous acid during its combustion. It is heavier than water, and many of its properties are analogous to those of acids. It may be decomposed by a gentle heat: sulphuretted hydrogen is given off, and sulphur remains.

SULPHUR AND CHLORINE.

Chloride of Sulphur.—52.
(1 S. 16 + 1 C. 36.)

(§ 126.) SULPHUR may be united directly with chlorine, by passing a current of the gas over it in a state of minute division, and at a gentle heat. Ten grains of the flowers will thus absorb nearly 30 cubic inches; which is nearly in the proportion of 16 to 36, the weights of the respective equivalents of the two bodies.

(§ 127.) Chloride of sulphur is a volatile fluid, of a red colour by reflected light, but green by transmitted light. It rises in vapour at a temperature below 200°; and emits fumes which affect the eyes, and occasion a flow of tears. Its specific gravity is 1.6. It does not redden the colour of dry litmus paper; but, when shaken up with water, a kind of ebullition and great disengagement of heat take place; sulphur is precipitated, and the liquid is found to consist of a solution of muriatic, sulphurous, and sulphuric acids. In this process the water is decomposed; its hydrogen passing to the chlorine, and forming muriatic acid; and the oxygen to the sulphur, with which it forms the latter acids.

SULPHUR AND NITROGEN.

(§ 128.) THERE is no known compound of sulphur with nitrogen.

SULPHUR WITH BROMINE AND IODINE.

(§ 129.) SULPHUR unites directly with iodine at a gentle heat, and probably enters into a similar combination with bromine. The precise composition, however, of the compounds is unknown. The iodide of sulphur is a black, radiated solid, easily decomposable by heat: the iodine rising in vapour at a temperature but little above that at which the two bodies combine.

PHOSPHORUS.—12. ?

(§ 130.) PHOSPHORUS has never yet been found in nature in its simple form, but may be obtained by the following process, the explanation of which will be given upon a future occasion.

Take a quantity of bones that have been calcined (burnt in an open fire), reduce them to a fine powder, and digest them for two or three days with half their weight of concentrated sulphuric acid; adding as much water as may give the mixture the consistence of a thin paste. At the expiration of the time twice the bulk of boiling water must be stirred up with it, and the liquid separated by filtration. The solution, which will be very acid, is then to be evaporated to the thickness of syrup, mixed with one-fourth its weight of charcoal in powder, and strongly heated in an earthen retort; the beak of which must be plunged under water. The heat must be slowly raised till it becomes very intense. A large quantity of gas will escape during the process, and spontaneously inflame upon passing through the water into the air, and the phosphorus will distil over in drops, and congeal in the water. The process is troublesome, and not unaccompanied with danger in unskilful hands.

(§ 131.) Phosphorus, as thus obtained, is a soft solid, of a flesh-red colour; but, when purified by a second distillation, may be obtained colourless and perfectly transparent. Its specific gravity is 1.77. It is highly inflammable, and it is necessary to preserve it under water in well-closed bottles. It may be readily cut with a knife. When air is carefully excluded it melts at about 110°, and boils at 550° of Fahrenheit. In melting, it is necessary to keep it under water, to prevent it from bursting into flame. It may be set on fire by friction, as is commonly known from the phosphorus bottles, in which it is employed for the purpose of obtaining instantaneous light. It is tasteless, and

insoluble in water, but proves highly poisonous when taken into the stomach.

In the atmosphere, it emits a light smoke and peculiar smell, not unlike that of garlic; and a pale greenish, very beautiful light arises from it in the dark. This is owing to a slow combustion; and if a stick of phosphorus be confined in a jar full of common air over water, the whole of the oxygen will gradually disappear, and the nitrogen remain. It is soluble in oils, and communicates to them the property of shining in the dark. In pure nitrogen it is not luminous at any temperature.

There are some doubts with regard to the proportion in which this element enters into combination; owing to some peculiar difficulties in the analysis of its compounds. Such topics of controversy it is impossible for us, as we have before stated, to enter upon in a work like the present; but we must content ourselves with giving, in this and similar instances, that explanation of the facts which appears to us the best supported by the evidence.

Phosphorus and Oxygen.

Phosphorous Acid.—20.

(1 P. 12+1 O. 8.)

(§ 132.) The product of the slow combustion above described is a mixture of phosphor*ous* and phosphor*ic* acids, and may be obtained by placing two or three sticks of phosphorus in a funnel set upon an empty bottle a highly acid liquid may thus be collected, consisting of a solution of the two acids in the water, which they attract from the atmosphere. No good process, however, is known by which they may be separated; and the pure phosphorous acid is best obtained by passing the vapour of phosphorus through a substance, before referred to (§ 23), called corrosive sublimate, heated in a glass tube. The liquid product is to be mixed with water, and heated till it becomes of the consistence of syrup. It is then a compound of pure phosphor*ous* acid and water, which crystallizes on cooling. The process will be explained hereafter. When phosphorus is heated in highly rarefied air, a white powder forms upon it, which is volatile, and supposed to be the phosphorous acid in its anhydrous state: when heated in the open air, it takes fire, and it readily dissolves in water, to which it communicates an intensely sour taste.

(§ 133.) *Hydro*-phosphorous acid emits a disagreeable odour, and yields, when heated, penetrating white vapours. It has a strong tendency to unite with a further proportion of oxygen, which it absorbs slowly from the air, and becomes converted into phosphor*ic* acid. The investigation of the composition of this acid is one of considerable difficulty; but the most probable inference from experiment is, that it is constituted of one equivalent of phosphorus, and one of oxygen, and that its number consequently is 20.

Phosphoric Acid.—28.

(1 P. 12+2 O. 16.)

(§ 134.) We have already stated (§ 39) that phosphorus burns in oxygen gas with a splendour which the eye cannot bear. Its inflammation also in atmospheric air is brilliant and violent. In each case, copious white vapours are produced, which fall like snow to the bottom of the vessel in which the experiment is conducted. This is pure, anhydrous, phosphoric acid.

It may also be more conveniently formed by the action of phosphorus on nitric acid. Small fragments should be cautiously dropped into the acid, gently heated in a retort. The latter is decomposed; the action is very violent, and a large quantity of deutoxide of nitrogen is disengaged, a portion of the oxygen with which it was previously combined (§ 71) passing by elective affinity to the phosphorus. The solution obtained by this process is to be evaporated to dryness: in which state it consists of phosphoric acid, united with a proportion of water. Solid phosphoric acid may be united with water in any proportion beyond 20 per cent.; but, on heating the solution in a platinum vessel, the greater part of the water may be expelled: the residue fuses at a low red heat, and concretes on cooling into a kind of glass to which the name of *glacial* phosphoric acid was formerly given. It volatilizes unchanged at a high temperature, and is a compound of

3 equivalents phosphoric acid	36
1 ditto of water	9
	45

100 grains of phosphorus have been found, from the most careful experiments, to condense, by the first process 135 grains of oxygen, which is ver

nearly in the proportion of 12 to 16, or of

1 equivalent phosphorus . .	12
2 ditto oxygen . . .	16
	28

It is a deliquescent substance, and dissolves in water, with a hissing noise. It is inodorous, very sour, and volatile at a bright red heat.

The acid obtained by the decomposition of bones for the manufacture of phosphorus, as above described (§ 130), consists of phosphoric acid, which in that process is decomposed by the charcoal; giving up its oxygen to superior affinity, at a high temperature, and disengaging the inflammable element.

Hypo-phosphorous Acid.—32.

(2 P. 24+1 O. 8.)

(§ 135.) A third compound of phosphorus and oxygen may be formed, by acting upon water with a substance, hereafter to be described, called *phosphuret of barytes*. An insoluble precipitate is formed, from which the liquid is to be separated by filtration. To this solution sulphuric acid is carefully added as long as any precipitate is formed. The sour liquid which remains, after a second filtration, is to be concentrated by evaporation, when a viscous, uncrystallizable, acid fluid will be obtained, to which the name of hypo-phosphorous acid (§ 60) has been given. Its analysis proves that it contains less oxygen than the phosphorous acid, and that it is most probably a compound of

2 equivalents of phosphorus	24
1 ditto of oxygen .	8
	32

PHOSPHORUS AND HYDROGEN.

Proto-phosphuretted Hydrogen—14*.

(1 P. 12+2 H. 2).

(§ 136.) When the solid hydro-phosphorous acid (§ 132) is heated in close vessels, out of the contact of the air, a large quantity of gaseous fluid is given off, and may be collected in the usual way over water; which, however, absorbs about one-eighth of its volume. By this process, the water in the hydrophosphorous acid is decomposed: part of the phosphorus combines with a further portion of oxygen at its expense, and becomes converted into phosphor*ic* acid; while another portion unites with the hydrogen, and forms the proto-phosphuretted hydrogen.

(§ 137.) This gas is colourless, and possesses a very disagreeable smell. It does not spontaneously inflame when brought into contact with atmospheric air; but when mixed with it, or pure oxygen, it detonates violently with the electric spark, or when heated to 300° of Fah. 100 cubic inches weigh about 29.5 grs. One part of it in volume requires two parts of oxygen for its complete combustion; one volume of which unites with the hydrogen, which, in the compound, is condensed into half its bulk, and the remaining volume unites with the phosphorus, and forms phosphoric acid. Its constitution therefore is

1 equivalent phosphorus .	12
2 ditto hydrogen . .	2
	14

The condensation of the two volumes of hydrogen into one, may be shewn by heating sulphur in this gas: decomposition ensues, a double volume of sulphuretted hydrogen is produced, and a combination of sulphur and phosphorus precipitated

Per-phosphuretted Hydrogen.—13.

(1 P. 12+1 H. 1).

(§ 138.) A SECOND compound of phosphorus and hydrogen may be obtained in the following manner:—Into five parts of water put half a part of phosphorus cut very small; add one part of granulated zinc, and three parts of strong sulphuric acid. The gas will be disengaged in small bubbles, which spontaneously take fire as they reach the air upon the surface of the fluid. This is a very beautiful experiment. The gas may also be obtained by boiling phosphorus in a small retort, with a hot solution of potash, which should entirely fill the vessel. The neck of the retort being made to dip into a small bowl filled with the same solution, the gas, as it is extricated, gradually expels the liquid from the neck, and inflames when allowed to escape into the air; or may be collected in small quantities under a bell glass, also filled with the alkaline solution. Some caution is required in collecting the gas for examination; and at the commencement

* The prefixes *proto* and *per* denote the lowest and highest degree in which one body unites with another.

of the process, it should be generated very slowly, that any air contained in the apparatus may not be too suddenly decomposed.

(§ 139.) Perphosphuretted hydrogen is a colourless gas, possessing a highly offensive smell, resembling that of garlic. It is very slightly soluble in water: 100 cubic inches of it weigh about 27.5 grains.

Its most peculiar property is that of spontaneously inflaming on mixture with air or oxygen gas. This inflammation is accompanied by a very beautiful appearance. After the explosion, a circular, horizontal ring of dense white smoke rises in the air, which preserves its form for a long time, and increases its diameter as it ascends. Phosphoric acid and water are the products of its combustion. It deposits phosphorus when allowed to stand some time in a glass receiver, and may be resolved into its elements by passing through it a succession of electric sparks: phosphorus is precipitated and an equal bulk of pure hydrogen remains.

If, therefore, from the weight of 100 cubic inches of perphosphuretted hydrogen 27.5 grains, we deduct the weight of an equal bulk of hydrogen, 2.1 grains, (§ 41), the remainder 25.4 will be the weight of the phosphorus in the compound: which is very nearly in proportion of the two equivalents

1 equivalent	phosphorus .	12
1 ditto	hydrogen . .	1
		13

When sulphur is heated in this gas an equal volume only of sulphuretted hydrogen is the result.

Phosphorus and Chlorine.

Proto-chloride of Phosphorus.—48.

(1 P. 12+1 C. 36).

(§ 140.) We have already stated (§ 132) that, by passing the vapour of phosphorus over corrosive sublimate heated in a glass tube, a liquid product is obtained: this is a combination of phosphorus and chlorine.

(§ 141.) It is transparent and colourless, of the specific gravity of 1.45. It does not affect the colour of dry litmus paper; but the fumes, which it gives off in abundance, are acid, owing to the contact with the moisture of the atmosphere. It acts energetically upon water; the hydrogen combining with the chlorine and forming muriatic acid, and the oxygen with the phosphorus, by which the phosphorous acid is produced as before described (§ 132); in which process the muriatic acid is driven off by heat, and pure phosphorous acid remains.

From the most careful experiments it appears, that the proto-chloride of phosphorus is a compound of

1 equivalent	phosphorus .	12
1 ditto	chlorine . .	36
		48

Per-chloride of Phosphorus.—84.

(1 P. 12+2 C. 72.)

(§ 142.) When phosphorus is introduced into chlorine it inflames spontaneously, and burns with a pale flame. The product is a white solid, which condenses upon the sides of the vessel.

(§ 143.) It is volatile at a temperature below 212°; but may be fused under pressure, and crystallizes in cooling. It acts with violence upon water, forming with its elements muriatic and phosphor*ic* acids.

One grain of phosphorus unites with six of chlorine, when burned in that gas; which is in the exact proportion of

1 equivalent	phosphorus .	12
2 ditto	chlorine . .	72
		84

Phosphorus and Iodine.

Iodide of Phosphorus.

(§ 144.) Phosphorus and iodine very readily enter into combination by mere contact in the cold: during their action on each other much heat is given out; but the nature of the product has not been minutely examined. When the iodide is thrown into water, hydriodic and phosphoric acids are formed, and it is by this process that the former is best obtained, (§ 110.)

Phosphorus and Sulphur.

Phosphuret of Sulphur.

(§ 145.) Phosphorus and sulphur act with great violence on each other, and, it is probable, give rise to various compounds, in different proportions, which have not been completely examined. The combination may be effected by agitation under water, the temperature of which should not exceed 140° or 160° of Fahrenheit. The compound has a reddish-brown colour, and is fluid about

40° of Fahrenheit, or at the average temperature of the atmosphere. It does not act on water. It is more inflammable than phosphorus, and forms a good composition for phosphoric fire-matches. It may be distilled unchanged at a strong heat.

(§ 146.) It may here be stated, that the chemical nomenclature which designates the binary compounds of substances of the electro-negative class, which are not acid, by the termination *ide*, as *oxide*, *chloride*, *bromide*, &c., distinguishes by the termination *uret* analogous combinations of substances of the electro-positive class, which are not of a metallic nature. Thus we have *phosphuret*, *sulphuret*, *carburet*, &c.; the further application of which we shall become acquainted with as we proceed.

Selenium.—40.

(§ 147.) Selenium is another of those rare substances, hitherto undecomposed, with which the rapid progress of chemistry has lately made us acquainted. Neither the utility nor the interest of the subject will require us to describe at length the combinations of an element which many accomplished chemists have never had an opportunity of seeing.

In the process for obtaining sulphuric acid at Fahlun in Sweden, from a natural combination of sulphur and iron, called pyrites, it was observed, that a reddish mass was deposited, which, in burning, gave out a peculiar odour. The principal portion of the mass was sulphur; but with it was mixed a very minute quantity of the substance to which the name of *selenium* has been given. Selenium, at common temperatures, is a brittle solid of a brown colour and metallic fracture: it has neither taste nor smell. When pounded, the particles stick together, and its powder has a deep red colour. It melts at a few degrees above the boiling point of water; and, when warm, is very ductile, and may be drawn into fine threads; which are red by transmitted, but grey by reflected light. It boils at a temperature of about 600°, and condenses either in opaque metallic drops, or, when large vessels are used, in flowers of the colour of cinnabar. Its vapour has a deep yellow colour. When heated in the flame of a candle, urged by a current of air from a blowpipe, it emits a strong smell of horseradish.

Selenium and Oxygen.

Selenic Acid.—56. (1 S. 40 + 2 O. 16.)

(§ 148.) The peculiar smell of horseradish arises from the combination of selenium with oxygen, which is formed by heating this substance in contact with atmospheric air: this is probably an oxide of selenium. But when selenium is dissolved in nitric acid, and the solution evaporated, so as to expel the excess of that acid, a white saline mass remains, which may be sublimed by raising the temperature, the colour of the vapour closely resembling that of chlorine. The selenic acid crystallizes in needles in the colder part of the apparatus.

(§ 149.) Selenic acid has a sour, and slightly burning, taste: it is very soluble both in water and alcohol. It is readily decomposed by all substances which have a strong attraction for oxygen. If sulphurous acid be passed into its solution, pure selenium will be thrown down in the state of a red powder, and sulphuric acid formed. It may be likewise precipitated by the immersion of plates of zinc or polished iron.

Selenic acid is composed of

1 equivalent of selenium .	40
2 ditto of oxygen	16
	56

Chapter IV.

On the Non-Metallic Fixed Elements —Carbon, Silicon, and Boron; and their Binary Compounds.

(§ 150.) Following up the arrangement which we have adopted as convenient, and with the hopes that, from its strong contrasts, it will be easily retained by the memory, we come now to a class of substances which are totally unaffected by any changes of temperature, to which the art of man has yet been able to expose them, and are only known in the solid form: they can be neither fused nor volatilized, and are, therefore, designated as *fixed*. They have been called Carbon, Silicon, and Boron: they are bad conductors of heat, and the first alone (and that not in its purest form) is a conductor of electricity.

After describing the mode of obtaining each of these substances and its distinctive characters, we shall describe such of its known binary combinations, with the preceding elements, as possess any interest, either from their striking properties, their illustrations of the laws

of chemical affinity, or their application to the arts.

Carbon.—6.

(§ 151.) Carbon, although but rarely met with pure and uncombined, is one of the most important elements in nature: its various compounds are more generally and abundantly distributed than those of any other substance, and it may be said to form the basis of the whole organic creation.

Carbon is well known by the names of *diamond* and *charcoal*, which two substances, although so different and almost opposite in *physical* characters, it is probable, from the most unexceptionable experiments, are *chemically* the same.

(§ 152.) Diamonds have been chiefly found in the East Indies and Brazil, disseminated in gravel or imbedded in sand-stone. They are considered as gems of the highest value. Their crystalline texture gives them a degree of hardness which is beyond that of any other known substance. They are transparent, and of various colours; and their specific gravity varies from 3.4 to 3.6. Diamond, when subjected to the most intense heat in close vessels, undergoes no change; but, if strongly heated in the open air, is entirely consumed. If this experiment be made in pure oxygen gas, the diamond will be burnt, the oxygen will disappear, and an equal bulk of carbonic acid gas remain, whose properties will be presently described. The product of the combustion is precisely the same as that of an equal weight of pure charcoal under the same circumstances.

(§ 153.) Charcoal may be obtained free from impurity, by burying pieces of wood in sand in a crucible or other convenient vessel, and exposing them for about an hour to a very intense heat. It is prepared, in the large way, by the distillation of wood in cast-iron cylinders; or, more roughly, by building up piles of wood in a pyramidical form, covering them over with clay or other earth, and leaving a few air-holes, which are closed as soon as the masses are well lighted. It may be also procured in the state of an impalpable powder, by passing the vapour of alcohol through a tube heated to redness.

Charcoal, formed from wood, is a black, brittle solid, easily pulverized, perfectly insipid and free from smell. It is insoluble, and is unchanged by any degree of heat in close vessels. It burns readily in atmospheric air, and with great splendour in oxygen gas: the product being pure carbonic acid and a little water; the latter arising from a minute proportion of hydrogen, which the charcoal retains with great obstinacy.

Fresh prepared charcoal has the property of absorbing a considerable quantity of the different gaseous bodies, amounting in some cases to 80 or 90 times its own volume. The quantity of this absorption appears to depend upon the original elasticity of the gases; those which possess this property in the highest degree, and have hitherto resisted all attempts to convert them into liquids by compression, are taken up in the smallest proportion, while those which have been so condensed are absorbed more freely. Of hydrogen gas it will absorb only 1.75 times its own volume, but of ammoniacal gas 90 times.

Charcoal possesses the singular property of resisting the putrefaction of animal substances; and meat which has become tainted may even have its sweetness restored by rubbing with charcoal, and may be long preserved sweet by being buried in its powder. It also produces the remarkable effect of destroying the colour and smell of many animal and vegetable substances. Common vinegar, by being boiled with it, becomes perfectly colourless; and red wines, rum, or brandy may be bleached by filtration through it. It is largely employed, for this purpose, in the process of sugar refining, and for preparing colourless crystals of citric acid and other vegetable productions. Charcoal prepared by calcining animal substances in close vessels, has been found most efficacious for these purposes.

Carbon and Oxygen.

Carbonic Oxide.—14.

(1 C. 6 + 1 O 8.)

(§ 154.) If we introduce into a gun-barrel, or retort, a mixture of equal parts of well-dried chalk and charcoal pulverised, and expose it to a strong heat, a large quantity of gaseous matter will be produced, which may be collected over the water bath. The product must be agitated with lime-water, and a considerable absorption will take place, after which the remaining gas will be carbonic oxide. In this process, iron or zinc filings may be substituted for the charcoal, with greater certainty of procuring the gas perfectly pure.

(§ 155.) Carbonic oxide is a gaseous body of an offensive smell, colourless, and insipid. It is a very little lighter than atmospheric air; 100 cubic inches weighing 29.65 grains. It is very sparingly soluble in water, and it does not in any way affect the colour of blue vegetable infusions. It is inflammable, and burns with a blue flame; but a lighted taper plunged into a jar full of the gas is instantly extinguished. No water is formed during its combustion, as may be ascertained by holding a cold bell-glass over its flame, which will remain bright and free from the dew which is instantly deposited by the combustion of hydrogen gas and its compounds under similar circumstances. It is noxious to animal life when received into the lungs; and, when respired for a few minutes, produces giddiness and fainting.

If carbonic oxide be mingled with an equal bulk of hydrogen, and passed through an ignited tube, the tube will become lined with charcoal, and water will be formed; as at a high temperature the hydrogen attracts oxygen with more force than carbon. When mixed with half its volume of oxygen, it may be exploded in a detonating tube by the electric spark, and 150 measures of the mixture will thus be converted into 100 of carbonic acid, a combination which will be described in the next section; after which the calculation will be better understood, from which its composition has been inferred to be

1 equivalent of carbon . . .	6
1 ditto of oxygen	8
	14

The blue flame which may be observed over burning charcoal arises from the combustion of this gas.

Carbonic Acid.—22.

(1 C. 6+2 O. 16.)

(§ 156.) We have just seen (§§ 152, 153) that diamond and charcoal may both be burnt in oxygen: the bulk of the gas is not altered, but its weight is increased by the exact amount lost by the solids during the combustion; and all its properties are changed. Carbonic acid, however, is most conveniently obtained by dropping fragments of marble or chalk into muriatic acid, diluted with two or three times its weight of water. A strong effervescence ensues, the gas from which may be collected over the water bath.

(§ 157.) Carbonic acid gas is colourless and inodorous. It is rather more than by one-half heavier than common air; 100 cubic inches weighing 46.5 grains. It is perfectly uninflammable, and instantly extinguishes flame. From its great specific gravity, it will remain for some time at the bottom of a jar with its mouth turned upwards; and may be poured from one such vessel into another like water. It is an amusing experiment to place a lighted taper in the bottom of the jar, as it will be instantly extinguished by pouring the gas upon it, like a liquid.

It is speedily fatal to animals which breath it: and hence the danger of exposure to the fumes of burning charcoal, which have in so many instances proved fatal. From its great density, it also not unfrequently collects in the bottoms of wells and mines, while the upper parts are free from it, and, from its injurious effects, is called by the miners *choak damp.* It has been condensed into a liquid by a pressure amounting to that of 36 atmospheres, or a column of mercury 90 feet in height.

Water, under common circumstances of pressure and temperature, will dissolve about its own bulk of this gas; but the quantity taken up may be increased by pressure, and will, in fact, be in exact proportion to the compressing force. It is by the strong compression of a forcing-pump that the common soda-water is so highly charged with this gas.

The solution has an agreeable subacid taste, and reddens paper, stained with the blue colour of litmus. When, however, an infusion of litmus, which has been reddened by this acid, is boiled, the blue colour returns as the acid escapes: an effect which distinguishes it from all other bodies of the same class. The pleasant pungency of brisk and sparkling fermented liquors is owing to the carbonic acid which they hold in solution, and which they lose upon exposure to the air, and become thereby flat and stale.

Carbonic acid is produced in all the common cases of combustion, and is likewise abundantly formed during the respiration of animals; it is not, therefore, surprising that it should be always present in the atmosphere to the amount of about one-thousandth or one-fifteen-hundredth of its bulk. Indeed, the great wonder is, considering the abundance of its sources, that it does not accumu-

late to an injurious degree, as it certainly would, without one of those admirable and providential compensations which perpetually strike us amongst the laws of nature, and which we shall hereafter find in the vegetable part of the creation; by which it is provided, that the process of vegetation should remove the contamination produced by the animal part.

As it has been proved that oxygen, in uniting with carbon to form carbonic acid, does not alter its volume, it is easy to deduce the constitution of this body from its weight:

	Grains.
If from the weight of 100 cubic inches	46.5
we deduct the weight of 100 cubic inches of oxygen .	33.8
the remainder . . .	12.7

will be the weight of the carbon in the compound; and the proportion of 33.8 to 12.7 is very nearly the same as 16 to 6, or

1 equivalent of carbon . . .	6
2 ditto of oxygen . . .	16
making the equivalent of carbonic acid . . .	22

When a succession of electrical sparks is passed through carbonic acid gas, confined over mercury, a portion is converted into carbonic oxide and oxygen; and when a stream of it is passed over charcoal, ignited in a porcelain tube, it is wholly converted into carbonic oxide.

It will now be understood, that as carbonic oxide becomes converted into carbonic acid, by explosion with half its bulk of oxygen, and as the oxygen in carbonic acid is equal in volume to the acid, the quantity of oxygen in the former compound is exactly half that in the latter, and the composition of the oxide must be as before stated (§ 155.)

1 equivalent carbon . .	6
1 ditto oxygen . .	8
equivalent of carbonic oxide . .	14

Carbon and Hydrogen.

Sub-carburetted Hydrogen.—8.

(1 C. 6 + 2 H. 2.)

(§ 158.) By stirring the bottom of any stagnant pool of water, especially if it consist of clay containing vegetable substances in a state of decomposition, a quantity of gaseous matter will be disengaged, which may be collected in an inverted bottle, provided with a funnel. This, after being washed with lime-water, or a solution of potash, will consist of sub-carburetted hydrogen nearly in a state of purity.

(§ 159.) It is a colourless, permanent gas, soluble in very minute proportions in water, with very little odour, and inflammable. When set on fire it burns with a yellow flame, and gives out much more light than hydrogen: 100 cubic inches weigh 16.94 grains.

When mixed with atmospheric air or oxygen, in certain proportions, it explodes with violence upon contact with flame.

To decompose it completely, it is necessary to mix it with rather more than twice its bulk of oxygen gas; but exactly two volumes are consumed. Water and a quantity of carbonic acid are produced, the latter being precisely equal to the original bulk of the inflammable gas. Now, as carbonic acid contains its own bulk of oxygen (§ 156), half the oxygen in the above experiment must be taken up by the formation of that body: the other volume would require, to convert it into water, two volumes of hydrogen (§ 46): two volumes of hydrogen must, therefore, have been present in the volume of the sub-carburetted hydrogen originally employed.

Deducting, therefore, from the weight of 100 cubic inches of this gas	16.9
the weight of 200 cubic inches hydrogen	4.2 (§ 41)
the remainder	12.7

will be the weight of carbon in the compound; and the proportions 12.7 : 4.2 approach very nearly to those of

1 equivalent carbon - -	6
2 ditto hydrogen - -	2
	8

The fire-damp of coal-mines almost wholly consists of this gas, and the dreadful explosions which so often prove destructive to human life are occasioned by the ignition of its mixtures with atmospheric air at the candles of the miners.

It is necessary here to state that, when sub-carburetted hydrogen and chlorine are mixed together over water, no action takes place if light be carefully excluded; but if exposed to the light of day, and still more rapidly in the light of the sun, a series of decompositions ensues. Muriatic and carbonic

acids are formed, the former of which is instantly absorbed.

Carburetted Hydrogen.—14.

(2 C. 12 + 2 H. 2.)

(§ 160.) By gently heating, in a glass retort, three measures of strong sulphuric acid and one measure of alcohol, or pure spirits of wine, the mixture becomes black and thick, and a copious disengagement of gaseous matter takes place, which may be collected over water: after agitation with lime-water, or solution of potash, pure carburetted hydrogen remains.

(§ 161.) It is colourless, possesses very little smell, and is slightly soluble in water. It is inflammable, and burns with a dense bright flame, giving out much more light than the sub-carburetted hydrogen. It is very little lighter than common air, 100 cubic inches, weighing 29.65 grains. When mingled with oxygen gas and ignited, it explodes with great noise and violence. To insure its complete combustion, it should be mixed with five times its volume, of which, however, three only are taken up by the combustion. If too little oxygen be used, much of the charcoal is precipitated unburned. The products are water and two volumes of carbonic acid, indicating double the quantity of carbon in the preceding compound. The composition, therefore, of carburetted hydrogen is as follows:—

2 equivalents carbon . .	12
2 ditto hydrogen .	2
	14

the two volumes of hydrogen, as with the sub-carburet, being condensed into one.

Its specific gravity exactly agrees with this calculation; for 100 cubic inches, by the above decomposition, give 200 cubic inches of carbonic acid, which

weigh	93 grains	(§ 157)
from which, deducting the weight of 200 cubic inches oxygen	67.6	(§ 37)
the remainder, . .	25.4, will be the weight of carbon in 100 cubic inches of the gas; and if to . . .	
	25.4	
we add the weight of 200 cubic inches of hydrogen	4.2	(§ 41)
the total	29.6	

will be the weight of 100 cubic inches of carburetted hydrogen, as we have just stated.

The condensation of the hydrogen may be proved in another way: carburetted hydrogen, like phosphuretted hydrogen (§ 137), may be decomposed by single elective affinity with sulphur, which has a greater attraction for hydrogen than carbon. If, therefore, we heat sulphur in a measure of the gas over mercury, carbon will be precipitated, and two measures of sulphuretted hydrogen will be obtained: hydrogen, as we have seen (§ 122), not having its volume changed by combination with sulphur.

(§ 162.) The detonation of these gases with oxygen, which is extremely violent, would not be unaccompanied with danger in the apparatus which was formerly described (§ 46); but may be securely and accurately effected by the following simple means:—A strong glass tube must be provided, of the interior diameter of from two-tenths to four-tenths of an inch; it must be bent in the form of a syphon, with legs of nearly equal length: one end must be hermetically sealed (closed by the heat of a lamp urged with a blow-pipe), and the other open, and a little enlarged, in the manner of a funnel. Two platina wires must be inserted close to the sealed extremity, by which an electrical spark may be passed. The closed end must be graduated by the successive introduction of equal weights of mercury, and marking upon the glass the space which they occupy.

The syphon must be filled with water, or, in cases where the gases may be absorbable by that fluid, with mercury; and a portion of the gases, previously mixed with great accuracy, may easily be introduced above the fluid in the sealed end of the tube. It must next be removed from the trough in which it has been filled, by applying a finger upon the orifice. The fluid may be adjusted to the same level in the two legs, by either adding a few drops or expelling some, by the immersion of a piece of wood. The volume of the included gas must next be accurately measured by the graduation. The finger is now to be replaced upon the orifice, and a portion of air will be included between it and the fluid; which, when the electrical spark is passed, and the explosion takes place, acts as a spring, the column of included mercury recoiling against it, and preserving the tube from fracture. Even when the detonation is strongest, nothing is felt but a slight pressure upon the finger, which, after the process, must be gently removed,

and the fluid again adjusted till it stands at equal heights in the two legs, when the residual gas may be measured with the greatest nicety.

(§ 163.) Carburetted hydrogen may be decomposed by passing it through red-hot tubes: at a low-red heat charcoal is deposited, and an equal volume of sub-carburetted hydrogen produced; but at a white heat the latter is also decomposed, and the gas is greatly increased in volume. Chlorine readily combines with this gas, even in the dark; and in this way a mixture of carburetted and sub-carburetted hydrogen may readily be separated. (§ 159.) The result of the combination is a yellow liquid, like oil, possessing a peculiar sweet taste and ethereal smell: it is volatile, and may be distilled without change. It may properly be distinguished by the name of *hydro-carburet of chlorine*. From the property of forming this oily substance, carburetted hydrogen was formerly called *olefiant gas*.

(§ 164.) All the common, but highly interesting phenomena of *flame*, are dependent upon the combustible gases which we have just been examining; and the important processes of artificial illumination are founded upon their properties. Flame is, in all cases, the combustion of explosive mixtures of inflammable gases or vapours with common air in different proportions; and, when continuous, is maintained by an uninterrupted flow of these elastic fluids into the atmosphere, with which they slowly mingle. That it cannot be regarded as mere combustion at the point of contact, may be proved by holding a taper within a large flame produced from alcohol: the flame of the taper will appear within the other, from which it will be distinguished by its difference of colour; proving, that there is oxygen even in its interior. The flames of lamps and candles are fed by a stream of inflammable gases and vapours, arising from the decomposition of wax, tallow, or oils; commenced by the application of heat from some exterior source, but continued by the high temperature which is kept up by the process itself. The quantity of light which flame emits is dependent upon the incandescence of minute particles of solid matter, which are thrown off during the combustion; and those flames, whose products are only gaseous matter, give very little light. The light of a stream of ignited hydrogen is scarcely visible in the day-light; but if a small coil of platinum wire be suspended in it, or some solid body in very fine powder, such as the oxide of zinc be projected through it, it becomes very luminous. Phosphorus burns in chlorine with a very pale flame, the product of the combustion being a very volatile substance (§ 143); but burned in oxygen it emits a most splendid light, owing to the ignition of the particles of solid phosphoric acid which are given off. Carburetted hydrogen gives out, during its combustion, much more light than the sub-carburetted, owing to the larger quantity of carbon which is disengaged; but if the mixture with oxygen be in such proportions as at once to burn the whole of the charcoal in its gaseous combinations, without previous deposition, the light becomes blue, and is greatly reduced in intensity. These different stages of combustion may all be observed in the flame of a common candle; at the bottom part, where the inflammable gases are given off in the smallest quantity, and where they are most intimately mixed with the air, the combustion is at once complete, and the light is blue and faint; the centre part, where the particles of charcoal, owing to a less admixture of oxygen, are thrown off in a solid state and become incandescent before they are finally burnt, is white and highly brilliant; and the upper, where the charcoal is in still greater quantity and much of it finally escapes combustion, is red and dull.

The heat of flames, even of those which give least light, as of hydrogen and spirits of wine, is intense; as is shewn by platinum wire becoming white hot in the parts where the combustion is perfect. The fact is also proved by certain instances, where combustion takes place without evolving sufficient heat to cause inflammation, as in the instance of the *flameless lamp* already referred to, (§ 31). This experiment may be varied by pouring a little ether into the bottom of a wide-mouthed glass; when, if a piece of heated platinum wire be held a little above its surface, it will become red-hot, but will not inflame the ether till it acquires a full white heat.

(§ 165.) Upon the necessity of an intense heat for the maintenance of flame is founded the properties of the *miner's safety lamp*, by which the oc-

urrence of those dreadful explosions, to which we have just referred (§ 159), has become much less frequent; and might most probably be wholly prevented, were it not for gross carelessness and some still remaining prejudice. In this beautiful contrivance, the flame of the lamp is covered with a tall cylinder of wire-gauze, securely screwed to it, which does not prevent the circulation of the air, and, from the fineness of its texture, obstructs but little light. The operation of the metallic gauze may be illustrated by bringing a piece of it down upon the flame of a candle or of coal-gas. The flame may thus, as it were, be cut in half; the lower part only remaining ignited, the upper being cooled below the constituent temperature of inflammation: that the cooled gaseous matter, however, passes through the tissue may be proved, by lighting it again upon the upper surface. Now, supposing an explosive mixture to penetrate to the flame of the lamp, protected in the manner which we have just described, it will burn within the wire-boundary which has been prescribed to it; but the cooling influence of the gauze will prevent its extension to the external atmosphere, and thus all danger is avoided. The safety of the lamp, of course, entirely depends upon the perfect state of the wire-tissue and the manner in which it is secured, so that no aperture may exist by which the flame may pass.

(§ 166.) The progress of science has lately introduced a great improvement in the art of illumination, by suggesting the decomposition of the different substances which yield the inflammable gases in establishments formed for the purpose, and conducting the pure elastic products through pipes to the situations where they are required to be burned; and where their consumption may be regulated to the greatest nicety, according to circumstances. Coal, oil, and rosin have been chiefly employed in this new manufacture; and that upon a scale which cannot but astonish those who recollect the first suggestion of a scheme, which was very generally deemed chimerical. Coal, when subjected to distillation in close vessels, at a red heat, gives out a large quantity of gas, consisting chiefly of sub-carburetted hydrogen, mixed with the other inflammable gases which we have just described. The sulphuretted hydrogen with which it is contaminated is removed, by passing it through lime, suspended in water by agitation. The specific gravity of well-purified coal-gas varies from 450 to 700. A large quantity of an impure carbon, called coke, is found in the retorts after the extraction of the gas.

Oil, by being allowed to trickle into a red-hot retort, half filled with coke or pieces of brick to increase the heated surface, is decomposed, and yields a large quantity of gas, which is much richer in carburetted hydrogen than coal-gas, and is, therefore, much better fitted for purposes of illumination. Its specific gravity varies from 800 to 950. It contains no admixture of sulphuretted hydrogen, and requires no purification; and as less of it is required for any given quantity of light, the atmosphere of a room is less heated and contaminated by its combustion. It is, however, considerably more expensive than the gas from coal; although the first outlay of capital for a manufactory upon a large scale is less on account of the smaller size of the necessary pipes and apparatus. Rosin, it has lately been discovered, by peculiar treatment, also yields an abundance of gas, equal in quality to that from oil, and at about one-fourth the expense: its smell, moreover, is much less offensive than that of either coal or oil-gas, and it has been introduced with success into several very large establishments. Wood is likewise capable of yielding inflammable gas, by distillation, in abundance; but it is so deficient in the compounds of carbon and hydrogen, as to be nearly worthless for illumination. In manufactories, however, of charcoal, in iron retorts for the making of gunpowder, the gas which is given off is led by a pipe under the cylinders, and is economically employed in maintaining their heat.

The sub-carburetted and carburetted hydrogen gases are the only compounds of carbon and hydrogen known, which assume the form of permanently elastic fluids. There are, however, a variety of other combinations of these two elements, in different proportions, which have not been clearly developed, some of which are the products of art and others of nature, the description of which we shall defer to a future occasion.

Carbon and Chlorine,
Per-chloride of Carbon.—120.
(2 C. 12 + 3 Chl. 108.)

(§ 167.) The union of carbon with

chlorine cannot be directly effected; and no action ensues upon strongly heating charcoal in that gas. We have, however, seen (§ 163), that a triple compound of carbon, hydrogen, and chlorine may be produced by the direct combination of carburetted hydrogen and chlorine. If this oily liquid be exposed to the direct rays of the sun, in an atmosphere of chlorine, it will be decomposed; muriatic acid will be produced by the abstraction of the hydrogen, and the carbon will attach itself to another portion of the chlorine. The experiment is not difficult of performance in a glass retort fitted with a stop-cock. The muriatic acid is absorbed, as it is formed by the admission of a little water and fresh chlorine, admitted as required.

(§ 168.) The per-chloride of carbon is a transparent, colourless solid, having very little taste, and possessing an aromatic odour, resembling that of camphor. Its specific gravity is 2. It is very brittle, and a non-conductor of electricity. It is volatile at common temperatures, and is sublimed in very transparent, colourless crystals. It melts at 320°, and boils at 360° Fahrenheit. It is scarcely combustible; but when held in the flame of a spirit-lamp, it burns with a red flame, and gives off much smoke and fumes of muriatic acid. It is little soluble in water, but is readily taken up by alcohol, and may be crystallized from that fluid on evaporation. It is also soluble in ether and oils. The results, both of its analysis and synthesis, concur in its being a compound of

2 equivalents of carbon .	12
3 ditto chlorine	108
	120

Chloride of Carbon.—42.

(1 C. 6 + 1 Chl. 36.)

(§ 169.) When the vapour of the per-chloride of carbon is passed through an ignited glass tube containing fragments of glass or rock-crystal, to increase the heated surface, it is partly decomposed; chlorine escapes, and a fluid passes over, which may be separately condensed.

(§ 170.) It is limpid and colourless; does not assume the solid form even at 0° Fahrenheit, and is volatilized at a temperature between 160° and 170°. Its specific gravity is about 1.5. It may be distilled without change, but undergoes decomposition at a red heat. It may be mixed with alcohol, ether, and oils, but not with water. It is not combustible except when held in the flame of a lamp, when it burns with a yellow light, and gives off much smoke, mixed with acid fumes. Its analysis shows it to be a compound of

1 equivalent of carbon . .	6
1 ditto chlorine	36
	42

Sub-chloride of Carbon.—48.

(2 C. 12 + 1 Chl. 36.)

(§ 171.) Another compound of carbon and chlorine has been accidentally formed, in very small quantities, in a manufactory of nitric acid, from nitre and vitriol, in Sweden. It was in the form of white feathery crystals, rather heavier than water, and insoluble in that fluid. It had a peculiar smell, resembling spermaceti, and was tasteless. It was soluble in alcohol and ether, and burned in the flame of a lamp with a greenish colour. It was decomposed into chlorine and carbon, by passing its vapour through a glass tube containing fragments of rock-crystal, heated red hot. It was ascertained to be composed of

2 equivalents of carbon .	12
1 ditto chlorine .	36
	48

Carbon and Nitrogen.

Carburet of Nitrogen, or Cyanogen.—26.

(2 C. 12 + N. 14.)

(§ 172.) By boiling together red oxide of mercury with twice its weight of the well-known colour called *Prussian blue*, in a sufficient quantity of water, a compound may be obtained which crystallizes in prisms, and which was formerly known by the name of prussiate of mercury, but is now designated as *cyanuret of mercury*. This substance well dried at a temperature below that of boiling water, when put into a small retort, or such a tube as that before described (§ 36), and exposed to heat, blackens and liquefies, and gives off a gas which may be collected over mercury.

(§ 173.) The carburet of nitrogen is a permanently elastic fluid at a common pressure and temperatures. Its smell is pungent and disagreeable. It is colourless, and burns with a purplish-blue flame, but extinguishes burning bodies. One hundred cubic inches of it weigh about 55 grains. It is soluble in water

and alcohol, the former of which takes up about four and a half times its volume, and the latter twenty-three times. It has been reduced to the liquid state by a pressure equivalent to that of 3.6 atmospheres.

When mixed with oxygen it may be exploded by the electric spark. It requires twice its volume of that gas for its complete combustion; and the products are two volumes of carbonic acid and one volume of nitrogen. Now, 200 cubic inches of carbonic acid contain, as we have seen (§ 161), 25.4 grains of carbon, and 100 cubic inches of nitrogen weigh 29.7 grains, making the weight of 100 cubic inches of cyanogen 55.1 grains, and agreeing very closely with its weight, as before stated, from experiment; there is, therefore, no difficulty in concluding that it is a compound of

2 equivalents carbon	. .	12
1 ditto nitrogen	. .	14
and that its combining proportion is	. . . .	26

The carburet of nitrogen, although a compound body, has the singular property of combining with elementary substances in a manner perfectly analogous to that of the simple gaseous bodies which we have previously examined. Thus, like chlorine, it forms acids by combining both with oxygen and hydrogen; and it is on account of this analogy that the appellation of *cyanogen** has been conferred upon it. The consideration of these *triple* compounds we must refer to a future chapter. We may here remark that carbon is, of all the elementary substances, the only one which is disposed to form *triple* combinations. One of these we have described in the *hydro-carburet of chlorine* (§ 163). The combinations of cyanogen (termed cyanurets) afford other instances of this tendency, and we shall find that they abound in the products of the animal and vegetable parts of creation.

Carbon and Sulphur.

Sulphuret of Carbon.—38.

(1 C. 6 + 2 S. 32.)

(§ 174.) Carbon and sulphur may be made to combine by the following process:—Place an earthen tube, of about an inch and a half diameter, a little inclined, across a chafing-dish, and nearly fill it with small pieces of charcoal well burned, and quite free from moisture. To the higher end adapt a glass tube filled with small pieces of sulphur, which may be pushed forward by means of a wire passing through a cork, which must be made carefully to exclude the air. To the opposite end a bent glass tube must be adjusted, which must pass down below the surface of some water contained in a bottle. When the fire in the chafing-dish has been lighted, and the centre of the tube become red hot, the sulphur must be thrust forward into contact with the ignited charcoal; and immediately bubbles of gas will escape from under the water in the bottle, and a vapour will appear which will condense under the water into a liquid. It may be rectified, or obtained quite pure, by re-distilling it at a heat not exceeding 110° Fah., in a glass retort containing a little muriate of lime (or chloride of calcium), to retain any water with which it may be mixed.

(§ 175.) The sulphuret of carbon thus obtained is a perfectly colourless and transparent fluid. Its taste is acrid, pungent, and somewhat aromatic: its smell nauseous and fetid in a very high degree. It is very volatile, and boils at common atmospheric pressure at a temperature not exceeding 110° Fah. It has never been congealed by the lowest artificial temperature. It is highly inflammable, and it burns with a blue flame, emitting copious fumes of sulphurous acid. No moisture whatever is deposited upon cold glass during its combustion, which is sufficient proof that it contains no hydrogen. It mixes readily with alcohol and ether, but not with water; the latter precipitates it from either of the former mixtures. Owing to its extreme volatility, it has been employed to produce great degrees of cold. A thermometer whose bulb has been covered with lint, and moistened with it, will sink rapidly from 60° to 0° Fah.; and, by a little management under the exhausted receiver of an air-pump, may be made to fall to even 70° or 80° below 0°; so that mercury may be readily frozen by its evaporation. The results of a careful analysis prove this remarkable fluid to be composed of

1 equivalent of carbon	. .	6
2 ditto sulphur	.	32
		38

* From two Greek words, signifying the *formation of blue*: the termination in *gen*, shewing its reference to hydrogen, oxygen, &c.

Silicon.—8.?

(§ 176.) Although silicon, in combination with oxygen, is one of the most abundant substances in nature, so much so as to entitle it to be considered the basis of the inorganic, as carbon is of the organic, creation, it is only very lately that the art of chemistry has succeeded in separating it in small quantities, by difficult and complicated processes. These are dependent upon the properties of substances which have not yet been described, and which are themselves of extraordinary character, and we shall therefore defer the details of its extraction till they can be better understood.

(§ 177.) Silicon has been obtained in the form of a solid, in a disintegrated state, of a dark brown colour, and without metallic lustre. It does not conduct electricity, and is incombustible either in air or oxygen gas. It may be exposed to the strongest heat without fusing or undergoing any other change. It decomposes water, and becomes converted into oxide of silicon, or silex, by union with its oxygen. Although much uncertainty still prevails in all experiments with this difficultly-obtained element, there is reason to suppose that, in the state of oxide, it is combined with its own weight of oxygen, and that its equivalent is 8.

Silicon and Oxygen.

Oxide of Silicon or Silex.—16.

(1 S. 8 + 1 O. 8.)

(§ 178.) Silex enters into the composition of most earthy minerals, and exists in a state of almost perfect purity, in the form of colourless rock-crystal or crystals of quartz. By heating these substances red-hot, and throwing them into water, they may be disintegrated and reduced to fine powder, by pounding. Sufficiently pure silex may also be obtained by calcining common flints at a low red heat. They may then be easily reduced to powder. In this state they must be mixed with four times their weight of carbonate of potash, and fused in a crucible, by a strong red heat. A strong effervescence will take place; after which the heat must be urged till the materials enter into complete and quiet fusion. The compound may be dissolved, when cold, in water; and the alkaline solution, after filtration, dropped gradually into diluted sulphuric or muriatic acid. An abundant precipitate will subside, which, after pouring off the liquid which covers it, must be thoroughly washed till the water comes away perfectly tasteless: it must then be dried.

(§ 179.) Silex thus obtained is a perfectly white and tasteless powder, which feels harsh between the fingers. Its specific gravity is 2.6. It is insoluble in water, and is not acted upon by any acid except the fluoric, whose properties will be hereafter described. When first prepared, and minutely divided, it is taken up by solutions of pure potash or soda, but not by the volatile alkali ammonia.

(§ 180.) Silex, in combination with the fixed alkalies, forms the basis of that inestimable product of art—glass. When one part of very pure sand is ignited with three of carbonate of potash, a compound is formed, which is very soluble, and deliquesces (attracts moisture) in the air. When these proportions are reversed, and three parts of sand and one of carbonate of potash are fused together, the product is insoluble in water and all the acids except the fluoric, and possesses the well-known properties of glass. Its purity depends upon the purity of the ingredients employed in its manufacture. Green bottle-glass is made of impure materials; such as sand, which contains a considerable proportion of iron, and the commonest kind of soda, called kelp. Window-glass is made of pure alkali, and sand which is free from iron; and for plate-glass the utmost care is taken to provide both the materials in their purest forms.

Boron.—6.?

(§ 181.) When equal parts of the metal *potassium*, and very pure boracic acid, are heated together in a copper tube, at a temperature of about 302° Fahrenheit, they suddenly become red hot: the metal disappears, and, when the product has been washed with warm water, a greenish-brown or olive-coloured substance is obtained, which is boron.

(§ 182.) It is insoluble in water, tasteless, and does not affect the colour of blue vegetables. It may be exposed to the strongest heat in close vessels without undergoing any change; but when heated to about 600° Fahrenheit in the open air, it burns vividly, absorbs oxygen, and is converted into boracic acid. It is a non-conductor of electricity.

Boron and Oxygen.

Boracic Acid.—22.

(1 B. 6+2 O. 16.)

(§ 183.) There is considerable discrepancy in the results of experiments upon the quantity of oxygen which is absorbed by boron during its combustion; but there is reason to think that 100 grains condense 266.6 grains of that gas, which is in the proportion of 6 to 16: so that, supposing the acid to be a compound of two equivalents of oxygen, the number for boron will be 6, and that for the acid 22. Boracic acid may be obtained by dissolving a given weight of a salt called *borax* (which is imported from India in a rough state under the name of *tincal*) in boiling water; and adding half its weight of sulphuric acid, previously diluted with an equal quantity of water. Upon evaporation of the solution and cooling, shining, scaly crystals will be precipitated, which is the substance in question. It is also found native in the neighbourhood of volcanoes.

(§ 184.) It is destitute of smell, and possesses very little taste. It is sparingly soluble in water, and the solution reddens vegetable blue colours; and, what is very singular, it also reddens the yellow colour of turmeric in the manner of alkalies. It is soluble in alcohol, and communicates a beautiful green colour to its flame. It fuses when heated, and gives off its water of crystallization to the amount of about 44 parts in the hundred. It is therefore probable that the crystallized acid is composed of

1 equivalent acid . .	22
2 ditto of water . .	18
	40

Chapter V.

On the further Combinations of the preceding Acids and Salifiable Base: or Salts of Ammonia.

(§ 185.) As it is by no means our object to compile a system of chemistry for proficients in the science, in which order and perfect arrangement would be one of the most essential considerations, but rather to lead the mind of the student by degrees from the simpler to understand the more complex phenomena of Nature, we here deem it right to pause, and offer a brief retrospect of the progress which we have made; from which it may be hoped, that the facts already stated, and which it is of the utmost importance to recollect with readiness, may be more surely fixed upon the mind. Our attention has hitherto been directed to the properties of twelve *non-metallic elements*, or substances, which have resisted all attempts to decompose them, and their binary compounds with one another. The arrangement which we have adopted with regard to the former, and the simple equivalent proportions in which they combine together, will readily be recalled by the means of the following Table:—

TABLE I.

NON-METALLIC ELEMENTS.

	Electro-Negative.	Equivalents.	Electro-Positive.	Equivalents
Aëriform..	Oxygen . . .	8		
	. . . . . .		Hydrogen . . .	1
	. . . . . .		Nitrogen . . .	14
	Chlorine . . .	36		
Volatile...	Bromine . . .	75		
	Iodine . . .	124		
	. . . . . .		Sulphur . . .	16
	. . . . . .		Phosphorus . .	12
	. . . . . .		Selenium . . .	40
Fixed....	. . . . . .		Carbon. . . .	6
	. . . . . .		Silicon . . .	8
	. . . . . .		Boron . . .	6

In Table II. we have arranged the binary compounds of the foregoing element in three divisions, viz., the Acid, the Alkaline or Basic, and the Neutral. The proportions in which they are combined is stated, and the equivalent number of each compound is added to it, shewing in what proportion it would enter into any further combination.

TABLE II.

BINARY COMPOUNDS OF THE NON-METALLIC ELEMENTS.

Equivalents.		Equivalents.		Acid. Electro-Negative.	Equivalents.	Alkaline or Basic. Electro-Positive.	Equivalents.	Neutral.	Equivalents.
1	Hydrogen	+ 1	Oxygen					Water	9
	Ditto	+ 2	Ditto					Peroxide of Hydrogen	17
1	Nitrogen	+ 1	Oxygen					Protoxide of Nitrogen	22
	Ditto	+ 2	Ditto					Deutoxide of Nitrogen	30
	Ditto	+ 3	Ditto	Hypo-Nitrous Acid	38				
	Ditto	+ 4	Ditto	Nitrous Acid	46				
	Ditto	+ 5	Ditto	Nitric Acid	54				
	Ditto	+ 1	Hydrogen			Ammonia	17		
1	Chlorine	+ 1	Oxygen					Protoxide of Chlorine	44
	Ditto	+ 4	Ditto					Peroxide of Ditto	68
	Ditto	+ 5	Ditto	Chloric Acid	76				
	Ditto	+ 8	Ditto	Per-Chloric Acid	100				
	Ditto	+ 1	Hydrogen	Muriatic Acid	37				
4	Ditto	+ 1	Nitrogen					Chloride of Nitrogen	158
1	Bromine	+ 5	Oxygen	Bromic Acid	115				
	Ditto	+ 1	Hydrogen	Hydro-Bromic Acid	76				
1	Iodine	+ 5	Oxygen	Iodic Acid	164				
	Ditto	+ 1	Hydrogen	Hydriodic Acid	125				
3	Ditto	+ 1	Nitrogen					Iodide of Nitrogen	386
1	Sulphur	+ 2	Oxygen	Sulphurous Acid	32				
	Ditto	+ 3	Ditto	Sulphuric Acid	40				
	Ditto	+ 1	Ditto	Hypo-Sulphurous Acid	24				
2	Ditto	+ 5	Ditto	Hypo-Sulphuric Acid	72				
1	Ditto	+ 1	Hydrogen	Sulphuretted Hydrogen	17				
2	Ditto	+ 1	Ditto	Bisulphuretted Ditto	33				
1	Ditto	+ 1	Chlorine					Chloride of Sulphur	52
1	Phosphorus	+ 1	Oxygen	Phosphorous Acid	20				
	Ditto	+ 2	Ditto	Phosphoric Acid	28				
2	Ditto	+ 1	Ditto	Hypo-phosphorous Acid	32				
1	Ditto	+ 2	Hydrogen					Proto-phosphuretted Hydrogen	14
1	Ditto	+ 1	Ditto					Per-phosphuretted Hydrogen	13
1	Ditto	+ 1	Chlorine					Proto Chloride of Phosphorus	48
1	Ditto	+ 2	Ditto					Per-Chloride of Ditto	84
1	Selenium	+ 2	Oxygen	Selenic Acid	56				
1	Carbon	+ 1	Oxygen					Carbonic Oxide	14
1	Ditto	+ 2	Ditto	Carbonic Acid	22				
1	Ditto	+ 2	Hydrogen					Sub-Carburetted Hydrogen	8
2	Ditto	+ 2	Ditto					Carburetted Hydrogen	14
1	Ditto	+ 1	Chlorine					Chloride of Carbon	42
2	Ditto	+ 3	Ditto					Per-Chloride of Carbon	120
2	Ditto	+ 1	Ditto					Sub-Chloride of Carbon	48
2	Ditto	+ 1	Nitrogen					Cyanogen	26
1	Ditto	+ 2	Sulphur					Sulphuret of Carbon	38
1	Silicon	+ 1	Oxygen					Silex	16
1	Boron	+ 2	Oxygen	Boracic Acid	22				

(§ 186.) The union of substances of the first division with those of the second, (that is to say, of acids with bases), gives rise to a very important class of compounds, to which the general name of salts has been given. The chemical nomenclature distinguishes them by changing into *ate* the termination of the acids ending in *ic*, or those which contain the largest proportion of oxygen (§ 60); and into *ite*, the termination in *ous* denoting an inferior proportion: as ni-

trate from nitric, nitrite from nitrous acid, or sulphate from sulphuric, and sulphite from sulphurous acid, and placing it before the name of the alkali, as the nitr*ate* of ammonia, the sulph*ite* of ammonia, &c. The general designation of *salifiable base* is also given to any body which forms a salt by combination with an acid.

The salifiable bases are not only distinguished by their property of saturating the acids, but also of being liberated from their combinations at the negative pole of the voltaic battery, when exposed to the repulsive power of electricity, while the acids appear at the positive pole.

The only salifiable base which is formed by the binary combinations of the non-metallic elements is ammonia, or, as it is sometimes called, the volatile alkali.

In the third division of the above table there are three compounds which enter, in the manner of elementary substances, into composition with other bodies; these are, water, silex, and cyanogen. To this property of the latter body we have before alluded (§ 173), and the nature of its compounds will be hereafter more fully investigated.

Of the combination of water in definite proportions with other bodies, we have given examples as forming the *water of crystallization* in salts (§ 81), which is essential to their constitution as crystals; and as a necessary constituent of the hydro-acids, as the *hydro*-nitric (§ 72) and *hydro*-sulphuric acids (§ 118). To the remaining definite compounds of water with different *salifiable bases* the term *hydrates* has been applied. In most of them it loses its fluid form, becomes fixed, and is often retained by so powerful an affinity, as not to be separated by the application of the most violent heat: of this species of combination many examples will occur in the sequel.

With regard to the third neutral body, silex, the nature of its union with other substances is less understood than that of any other class of compounds. They are chiefly found in the mineral kingdom, and will be carefully examined when we come to treat of the *analysis of minerals*. It has sometimes been ranked with the acids, or electro-negative compounds, on account of its affinities being chiefly exerted upon different bases hereafter to be described. Its few artificial combinations, of which glass is the most important, but which, according to the account which we have already given of its composition (§ 180), we are not at present warranted in classing with the definite compounds, will be noticed in the succession of the different bodies with which it unites.

Before we continue our account of the simple substances, by proceeding to enumerate the properties of the metallic elements, we deem it most conducive to our purpose, to describe the combination of the preceding acids with ammonia, and briefly to point out the properties of such of the salts of this base as possess any interest, or whose composition is sufficiently understood.

It may, perhaps, be objected to this arrangement, that we shall thus separate the ammoniacal salts from the great class of saline bodies, which are generally and conveniently arranged together; but, independently of certain peculiarities which might authorise such a separation, and which will be hereafter pointed out, we deem it justified by the facilities which it affords for illustration, and for the gradual application of the first elements of the science, of which it is our principal aim to render the acquirement as easy as possible.

The preceding details having strongly illustrated the fundamental law of chemical composition, that the equivalent numbers of the simple substances, or their multiples, are preserved in all their combinations with each other, the no less important remark will now be established, that when any body is compounded of two or more elements, and enters into union with another body, the sum of the equivalents of such elements will give the number denoting the proportion in which it will so combine (§ 27): a strong confirmation is thus incidentally afforded of the value of the equivalents previously determined.

(§ 187.) The salts of ammonia are distinguished as a class, by being all volatile, or decomposable by a strong heat. If the acid with which this base is combined be volatile, the salt will be sublimed without change; but if it be fixed, the ammonia will fly off, and the acid remain. Their taste is, in general, hot and biting; and they all emit the well-known smell of the volatile alkali, when mixed with caustic lime.

Nitrate of Ammonia.—Anhydrous 71, *Crystallized* 80.

(1 N. 54 + 1 A. 17 + 1 W. 9.)

(§ 188.) The composition and decomposition of this salt have been already described, for the purpose of illustration (§ 80). It readily deliquiates (attracts moisture from the air); and its most important property is that of yielding the protoxide of nitrogen when decomposed by heat (§ 61).

Muriate of Ammonia.—Anhydrous 54, *Crystallized* 63.

(1 M. 37 + 1 A. 17 + 1 W. 9.)

(§ 189.) Muriate of ammonia may be formed by mixing, over mercury, equal volumes of ammonia and muriatic acid gases, which will be entirely condensed into a white solid, which is the anhydrous salt; or it may be produced by neutralizing a solution of ammonia with solution of muriatic acid. Upon evaporation, the salt will be obtained in crystals containing, in addition, one equivalent of water. It is in this state that it is found in commerce under the name of *sal ammoniac;* and it is manufactured in abundance, by a complicated process, from bones and other refuse animal matters.

The salt possesses a pungent saline taste: it is readily soluble in water, producing a considerable reduction of temperature; and boiling water dissolves more than cold, the excess being deposited in crystals as the solution cools. It sublimes, without undergoing any change, at a temperature below redness. It may be passed, without alteration, through glass or earthenware tubes heated to redness; but, when transmitted over ignited metals, it is resolved into its gaseous elements.

The action of chlorine upon ammonia affords a singularly beautiful instance of the play of chemical affinities. When these two gases are suddenly mixed, they act so powerfully on each other, that a flash of white light accompanies the mixture; and when in the proportion of one part of the former to three of the latter, muriate of ammonia and nitrogen are the products. The chlorine takes hydrogen from one portion of the ammonia, liberating its nitrogen, and forms muriatic acid, which combines with the remainder of the ammonia to produce the salt. The experiment is very striking, and not difficult of performance in a rough way. For this purpose two wide-mouthed bottles may be fitted together, by grinding, in such a way that one may stand inverted upon the mouth of the other. One of these may be filled with chlorine, and placed with its mouth upwards, covered with a ground disk of glass. The other may be filled with ammonia, by holding it over a tube proceeding from another bottle containing a mixture of sal ammoniac and lime heated. The ammonia, as it rises, will displace the common air, and it may be known to be full by the escape of the pungent gas. The bottle may then be carefully placed, with its mouth always kept downwards, upon the bottle of chlorine, after removing the disk of glass, and the position of the two dexterously reversed. The heavy chlorine and the light ammonia will rush in opposite directions, and unite with the extrication of flame.

Muriate of ammonia is used in the arts for various purposes, and, amongst others, for preventing the oxidation of the surface of copper in tinning. The *aqua regia* of commerce, for the solution of gold, is formed by dissolving *sal ammoniac* in nitric acid.

Hydriodate of Ammonia.—142.

(1 H. 124 + 1 A. 17.)

(§ 190.) We have shown (§ 112) that when iodine is kept in a solution of ammonia, a new elective affinity is brought into action; part of it unites with the nitrogen of that compound, and is precipitated in the form of a brown powder, while another part combines with the hydrogen, and produces the hydriodic acid, which further neutralizes any excess of the alkali, and forms hydriodate of ammonia. This salt may also be formed by mixing the aqueous solutions of the acid and the base. It crystallizes in the form of cubes; is more soluble than the muriate of ammonia; and, like it, may be sublimed in close vessels without change. It is composed of equal volumes of hydriodic acid and ammoniacal gases.

Sulphite of Ammonia.

Anhydrous 49.—(1 S. 32 + 1 A. 17.)

Crystallized 107.—(2 S. 64 + 2 A. 34 + 1 W. 9.)

(§ 191.) This salt may be produced by the direct combination of its acid and base. It crystallizes in prisms; its taste is cool, and leaves a flavour of sulphur

in the mouth. It is soluble in its own weight of cold water, producing a considerable depression of temperature. Its solubility increases with heat, and a saturated boiling solution crystallizes on cooling. It rapidly attracts moisture and oxygen from the air, and is soon converted into a sulph*ate.*

Sulphate of Ammonia.

Dry 66.—(1 S. 40 + 1 A. 17 + 1 W. 9.)
Crystallized 75.—(1 S. 40 + 1 A. 17 + 2 W. 18.)

(§ 192.) This salt may be formed by neutralizing ammonia with sulphuric acid, or by the decomposition of either the muriate or carbonate of ammonia by the same acid, which has a superior affinity for the base. It crystallizes in small prisms; has a sharp bitter taste; is soluble in twice its weight of cold, and in its own weight of boiling water; and slowly attracts moisture from the air. The crystals contain two equivalents of water, one of which may be expelled by careful drying, but the other cannot be driven off without decomposing the salt. It is chiefly used for the manufacture of *sal ammoniac*, which is obtained by sublimation from a mixture of sulphate of ammonia and common salt.

Hydrosulphate of Ammonia.*—34.
(1 H. 17 + 1 A. 17.)

(§ 193.) When currents of sulphuretted hydrogen and ammonia are made to pass together into a vessel kept cool by ice, they combine, and the product crystallizes in transparent, colourless needles. This salt is probably composed of an equivalent of each ingredient. It is very volatile, and, when kept in glass, gradually sublimes to the top of the vessel. The same salt may be obtained in solution, by passing a current of sulphuretted hydrogen into liquid ammonia. It assumes very soon a greenish-yellow colour. It is much employed, as will be hereafter seen, as a test for metals in solution.

Carbonate of Ammonia.—39.
(1 C. 22 + 1 A. 17.)

(§ 194.) When dry carbonic acid is mixed over mercury with twice its volume of ammonia, complete condensation takes place, and a dry, white, volatile powder is produced. The taste and smell of this salt are the same as those of ammonia, but not so pungent. It converts the blue colour of vegetables to green. Hot water dissolves its own weight of it, and it is soluble in rather less than twice its weight of cold water. It speedily evaporates when heated; and when long kept, the ammonia escapes, and the residual salt is found to contain a larger proportion of carbonic acid.

Bicarbonate of Ammonia.

Crystallized 79.
(2 C. 44 + 1 A. 17 + 2 W. 18.)

(§ 195.) When a current of carbonic acid gas is made to pass through a solution of carbonate of ammonia. the base unites with a further equivalent of the acid, and a distinct salt is formed. When the solution is gently evaporated, it may be obtained in crystals, which have no smell, and very little taste. The same salt is also formed when gaseous carbonic acid and ammonia are made to act on each other *when water is present.* This liquid so far overcomes the elasticity of the gas, which prevents any further combination, when unopposed, as to enable it to unite with another equivalent of the acid; affording an illustration of the general observation which we have made (§§ 3, 15), that the repulsive power prevailing in aëriform fluids is opposed to chemical attraction.

(§ 196.) Salts which are thus constituted of two equivalents of their acid are distinguished by the Greek numeral *Bi* (two) prefixed to their names.

Sesqui-Carbonate of Ammonia.

Crystallized 118.
(3 C. 66 + 2 A. 34 + 2 W. 18.)

(§ 197.) Another compound of carbonic acid and ammonia is known, and commonly met with in commerce, under the name of carbonate of ammonia. It is obtained, by sublimation, from a mixture of muriate of ammonia and chalk. When fresh prepared it is of a crystalline texture, and semi-transparent, hard and compact. Its smell is pungent; its taste penetrating; and it affects the blue colours of vegetables in the manner of alkalies. Analysis has proved it to be a compound of carbonic acid and ammonia, in the proportion of three equiva-

* The chemical nomenclature is imperfect with regard to those acids into the composition of which hydrogen essentially enters; inasmuch as the prefix *hydro* is likewise employed to distinguish certain acids in combination with water (§ 72) from the same acids in an anhydrous state. The combinations of sulphuretted hydrogen, with salifiable bases, are sometimes termed hydro-sulphurets.

lents of the former to two of the latter. By exposure to the air it gradually loses weight, by throwing off one equivalent of its acid and its base, and becomes converted into the tasteless, inodorous *bi*-carbonate.

(§ 198.) To distinguish this constitution of a salt in the proportion of one and a half equivalent of acid to one of base (which is not a common occurrence) the term *sesqui* is prefixed to its name*.

(§ 199.) All the other acids named in the preceding table, form distinct and well-characterized salts, by combining in the proportion of their equivalents, and sometimes of their multiples, with ammonia; but they are not of importance enough to our object to require minute description.

Chapter VI.

On the Metals, the Oxides of which are reducible by mere Heat.

Mercury,	*Rhodium,*
Silver,	*Iridium,*
Gold,	*Osmium,*
Platinum,	*Nickel,*
Palladium,	

and their Binary Compounds.

(§ 200.) The metallic elements, to which we are now about to direct our attention form a highly interesting class; and are connected together by certain physical properties, which are common to them all.

They are opaque, and possess a lustre, even in their minutest fragments, so peculiar as to be well known to every one by the name of the *metallic lustre.* They are fusible at different degrees of heat, and when melted retain their opacity and brilliancy.

They reflect the greater part of the light and heat which falls upon their surface when polished, and form excellent mirrors. They are very good conductors both of electricity and heat. They belong to the class of electro-positive elements; passing, when subjected to the decomposing power of electricity, to the negative pole, from all their combinations with oxygen, chlorine, bromine, and iodine. They possess, in different degrees, a peculiar tenacity; which, when in its greatest perfection, renders them *malleable* and *ductile*, or capable of being extended under the hammer and drawn into wire.

The number of metals at present recognised amounts to about forty, and for the purpose of facilitating the acquirement, retention, and application of a knowledge of their properties, it will be proper to divide them into different orders or groups.

With this view, a convenient, though by no means a perfect, arrangement may be formed upon the different force of their affinity for oxygen; which varies so greatly, that at one extremity of the scale the gaseous element is capable of being driven off by the mere application of heat; while at the other it is so strongly retained, as to require the utmost power of the voltaic pile to effect its separation. By classing them in this way, we shall have the incidental advantage of separating those which, generally speaking, have been longest known, and are most eminently endowed with the characters of the genus, and of most value for all the common purposes of life, from those which are the fruits of recent discoveries, and, in their metallic state, useless, except in the hands of the scientific experimentalist.

Our first division consists of those metals, whose oxides are reducible to the metallic state by the application of heat alone. These are nine in number, viz., Mercury, Silver, Gold, Platinum, Palladium, Rhodium, Iridium, Osmium, and Nickel. On account of their great inalterability, they have been popularly designated as *Noble Metals.* Their properties we shall proceed to investigate, and those of such of their binary compounds as are calculated to interest and instruct.

Mercury.—200.

(§ 201.) Mercury, or quicksilver, is the only metal which assumes the fluid form at the ordinary temperature of the atmosphere. When cooled to about 40° below 0° of Fahrenheit, a degree of cold which sometimes occurs naturally in very high polar latitudes, it becomes solid. It can also be congealed by artificial freezing mixtures, and the evaporation of sulphuret of carbon (§ 175) in the vacuum of an air-pump. In this state it is malleable, and may be cut with a knife. Its colour is white, but rather bluer than that of silver: its specific gravity at 47° above 0° is 13.6. It is volatile, and its vapour rises in small quantities, even at the common temperature of the air. At about 660° Fahrenheit it boils rapidly, and may be purified by distillation.

It is found in nature, in small quan-

* A Latin word, denoting the whole of a thing and one half more.

tities, in the metallic state; but the ore from which it is chiefly extracted is a sulphuret, commonly known by the name of *cinnabar*.

Its combining proportion, or equivalent number, is known from the analysis of its binary compounds, of which we shall proceed to give some account.

Mercury and Oxygen.

Protoxide of Mercury.—208.

(1 M. 200+1 O. 8.)

(§ 202.) We have already stated (§ 23), that when mercury is violently agitated, for a long time, in contact with atmospheric air, it combines with its oxygen, and becomes converted into a black, insipid, insoluble powder, which consists of 200 parts of metal and 8 of oxygen. This protoxide may more readily be obtained by triturating in a mortar calomel, with a solution of pure potash or hot lime-water. It must be washed with cold water, and gradually dried in a dark place, as with access of light and heat it rapidly resolves itself into the peroxide and metallic mercury.

This oxide, if exposed to the air at a moderate heat, absorbs a further proportion of oxygen; but if distilled in a glass retort its oxygen is evolved.

Per-oxide of Mercury.—216.

(1 M. 200+2 O. 16.)

(§ 203.) The peroxide of mercury may not only be obtained by exposing the metal to the combined agency of heat and air, but also by dissolving it in nitric acid, and afterwards driving off the acid by a heat just sufficient for that purpose.

It is of a red colour, and sparingly soluble in water, to which it communicates the property of turning blue vegetable colours green. When distilled alone, in a glass tube, it yields oxygen gas, and the metal is revived. Careful analysis proves, that it contains just double the quantity of oxygen in the protoxide, or 8 parts in every 108.

Both the oxides of mercury combine with the acids, and constitute *salifiable bases*.

Mercury and Chlorine.

Proto-chloride of Mercury.—236.

(1 M. 200+1 C. 36.)

(§ 204.) When chlorine is brought into contact with mercury, at *common atmospheric temperatures*, the two substances combine in the proportion of one equivalent of each: but the proto-chloride may more easily be obtained, by pouring into the solution of the metal in nitric acid a solution of common salt or muriatic acid. It is precipitated in the form of a ponderous, white powder, which must be washed and dried at a gentle heat. Proto-chloride of mercury, or calomel, has a specific gravity of 7.2; it is tasteless, and nearly insoluble in water. When exposed to heat, it sublimes unaltered: when scratched, it exhibits a yellow streak, which may distinguish it from other bodies. It constitutes a well-known and highly useful medicine.

Bi-chloride of Mercury.—272.

(1 M. 200+2 C. 72.)

(§ 205.) When mercury is *heated* in chlorine, the two bodies combine together with a pale flame, in the proportion of one equivalent of the former and two of the latter. The bichloride, which is also well known by the name of *corrosive sublimate*, is prepared for medicinal purposes by intimately mixing together 73 parts of sulphate of mercury (formed by boiling together to dryness 50 parts of mercury with 70 of sulphuric acid) with 120 parts of common salt, and subliming. When thus obtained, it is of a crystalline texture, colourless, and semi-transparent. It is soluble in water, and highly poisonous. Its taste is acrid, burning, and metallic. Its specific gravity 5.2. It sublimes at a red heat, without change. If 272 parts, or one equivalent, of the bichloride be very intimately mixed, by trituration, with 200 parts, or one equivalent, of mercury, and the mixture sublimed, the proto-chloride will be obtained; and this is a common way of preparing calomel for use. When procured, however, by this process, it always contains a little corrosive sublimate; from which, after reducing it to powder, it should be carefully purified by washing.

Mercury and Sulphur.

Proto-sulphuret of Mercury.—216.

(1 M. 200+1 S. 16.)

(§ 206.) By long continued trituration together, mercury and sulphur combine in the proportion of one equivalent of each, and form a black-coloured powder. The same proto-sulphuret may also be obtained by transmitting a current of sulphuretted hydrogen through water, in which powdered calomel is kept sus-

pended. When exposed to heat, it is resolved into the bi-sulphuret and metallic mercury.

Bi-sulphuret of Mercury.—232.
(1 M. 200+2 S. 32.)

(§ 207.) WHEN mercury and sulphur are fused together, and afterwards sublimed, a red sulphuret is formed, which is known as a fine pigment by the names of *cinnabar* or vermilion. It contains exactly double the proportion of sulphur in the preceding sulphuret. It may also be prepared by pouring a solution of corrosive sublimate into a solution of hydro-sulphate of ammonia (§ 193). The precipitate which is obtained, is at first of a muddy-brown colour, but, when left undisturbed, gradually assumes the bright colour of cinnabar. It is from this compound, found in nature, that the mercury of commerce is procured. By mixing it with iron-filings and heating it, the sulphur passes to the iron, and the mercury is obtained by distillation.

SILVER.—110.

(§ 208.) SILVER is one of the metals which have been longest known to the inhabitants of the earth. It is of a beautiful white colour and great lustre. Its specific gravity is 10.5, and in malleability and ductility it exceeds all metals except gold. It may be extended into leaves, not exceeding $\frac{1}{100000}$th of an inch in thickness, and drawn into wire finer than a human hair. Its fusing point, measured by Daniell's pyrometer, upon Fahrenheit's scale, is about 2233°. It may be volatilized by a very strong and long-continued heat. When cooled slowly, and the liquid part of the metal poured off, as soon as the surface has congealed, it may be obtained in crystals. Its uses for money and for ornamental articles of luxury are well known, for which purposes it is well adapted by its great inalterability; but it is always alloyed with other metals, and generally with copper. The tarnish which affects it arises from sulphureous vapours, not from oxidation.

It is found in silver mines, in the metallic state, and also in combination with other metals and with sulphur.

SILVER AND OXYGEN.

Oxide of Silver.—118.
(1 S. 110+1 O. 8.)

(§ 209.) SILVER may be obtained in combination with oxygen by dissolving it in nitric acid, and mixing the solution with lime-water. After washing the precipitate with water, it should be dried at a temperature under redness. It is of an olive colour, insoluble in water, and tasteless. When heated to redness the oxygen is driven off, and the metal revived. It is composed of 110 parts of the metal and 8 of oxygen. It combines with the acids.

SILVER AND CHLORINE.

Chloride of Silver.—146.
(1 S. 110+1 C. 36.)

(§ 210.) SILVER combines with chlorine, and forms a compound well known by the name of *horn-silver*. It may be conveniently formed by adding a solution of silver in nitric acid to a solution of common salt. The white precipitate, which is the chloride of silver, becomes dark and finally black, if exposed to light, and especially to the direct rays of the sun. It is extremely insoluble in water, but readily taken up by ammonia. When heated to a dull red, in a silver crucible, it melts; and, on cooling, forms a semi-transparent substance not unlike horn. When fused with twice its weight of potash or soda it is decomposed, and a globule of pure silver obtained. A mixture of chloride of silver, chalk, and pearl-ash, is employed for silvering brass; such as thermometer-scales, clock-dials, &c. The metal is rendered very clean, and the mixture moistened with water well rubbed upon its surface. The results of the most careful analyses have proved it to be constituted of one equivalent of each of its ingredients.

SULPHUR AND SILVER.

Sulphuret of Silver.—126.
(1 S. 110+1 Su. 16.)

(§ 211.) WHEN thin plates of silver and sulphur are laid alternately above each other in a crucible, they combine together at a low red heat. The sulphuret is of a black colour, and capable of being cut with a knife. It is much more fusible than the metal. When strongly heated, the sulphur is slowly sublimed from it, and leaves the silver in purity. It is often found native in the mines. The same compound is also produced when sulphuretted hydrogen or hydro-sulphate of ammonia are

added to the solutions of the metal. It is a compound of 1 equivalent of the metal and 1 of sulphur.

Silver and Mercury.

Amalgam of Silver.—310.

(1 S. 110+1 M. 200.)

(§ 212.) The combinations of mercury with other metals are distinguished by the name of *amalgams;* some of them are definite compounds, and may be obtained in crystals, while others partake more of the nature of solutions. They are generally soft solids, of the consistency of butter.

Silver very readily combines with mercury; and a very sensible degree of heat is produced when silver-leaf and mercury are kneaded together in the hand. It is sometimes found native and crystallized; in which state its analysis has shown it to be composed of mercury 64, and silver 36—which is almost exactly in proportion of an equivalent of each. At a moderate heat the mercury evaporates and leaves the silver.

It is sometimes employed for an inferior kind of plating; for this purpose it is applied to the surface of copper, and the mercury being driven off by heat,. the remaining silver is burnished.

Gold.—200.

(§ 213.) Gold, when pure, is of a yellow colour, and possesses a specific gravity of about 19.3. It exceeds all other metals in ductility and malleability. It may be beaten into leaves $\frac{1}{280000}$th of an inch in thickness; and a wire of only $\frac{78}{1000}$ths of an inch diameter will sustain a weight of 150lbs. Its melting point is about 2590° of Fahrenheit's scale. It is perfectly unchanged by fire with access of air, and the intense heat of a glass-house furnace has no other effect upon it than to keep it in fusion. It is not acted upon by any solvent, except a mixture of muriatic and nitric acids, or the *aqua regia* before described (§ 189). Its great value for the purposes of coin, when slightly alloyed with other metals, is well known. From its great beauty, inalterability, and lustre, it is also in the highest request for purposes of luxury and ornament. It has hitherto only been found in nature in the metallic state, either pure or in combination with other metals.

Gold and Oxygen.

(§ 214.) Much uncertainty still exists with regard to the combinations of gold with oxygen. When a strong electric shock is passed through a fine gold wire or when in the state of thin leaf it is exposed to a strong current of electricity, from a voltaic battery, it is burnt, and a fine purple powder is the result, which there can be little doubt is an oxide of gold.

If gold be dissolved in a mixture of two measures of muriatic and one of nitric acids, the solution may be evaporated to dryness by a moderate heat, and the residual salt dissolved in water. A solution of pure potash may then be dropped into it, when, with the assistance of a moderate heat, a reddish yellow-coloured precipitate will be formed, which is also an oxide of the metal, combined with a portion of water. It may be rendered anhydrous by boiling, and it then assumes a brownish-black colour. It is insoluble in water, and it parts with its oxygen by exposure to solar light, or at a red heat. It is most probably a peroxide, and consists of one equivalent of gold 200, and 3 equivalents of oxygen 24, making its number 224. It is taken up by some of the acids.

Gold and Chlorine.

(§ 215.) The same degree of uncertainty exists with regard to the chlorides as to the oxides of gold. Gold leaf introduced into chlorine gas takes fire and burns; and if it be suspended in water, into which the gas is passed, it is dissolved, and the solution may be concentrated by evaporation. The solution obtained in the manner directed in the last section, consists also, most probably, of the same per chloride. By exposure to a moderate heat it parts with two-thirds of its chlorine, and is converted into a yellow insoluble protochloride.

Gold and Sulphur.

Per-sulphuret of Gold.—248.

(1 G. 200+3 S. 48.)

(§ 216.) Sulphur, even when assisted by heat, has no action on gold; but when a current of sulphuretted hydrogen is passed through a solution of that metal, a black precipitate is formed, which is a true sulphuret of gold. The sulphur may easily be expelled from this combination by heat. It is composed of

1 equivalent gold . . .	200
3 ditto sulphur	48
	248

Gold and Mercury

Amalgam of Gold.

(§ 217.) Mercury dissolves gold with great facility; and the amalgam is used, in the arts, for gilding. When applied upon the surface of the metals the mercury is driven off by heat, and a thin coating of gold remains: the process is called *water-gilding*. The amalgam may be obtained in crystals, in which case there can be no doubt that it is a definite compound.

Platinum.—96.

(§ 218.) Platinum, although only found in the metallic state, is comparatively but a late discovery. The general appearance of it in the rough state, in which it is brought to this country, is that of small grains or scales, darker than silver, and extremely heavy.

When purified it is of a white colour, lighter than that of iron, and exceeding all other metals in specific gravity: it being 21.5, and the most ponderous of all known substances. It is extremely difficult of fusion, but may be melted by a flame urged with oxygen gas. It possesses the valuable property of *welding*; that is to say, at a white heat an incipient fusion takes place, which covers its surface with a kind of varnish, so that, when brought into contact in this state, different pieces may be permanently united by forging. In this manner it can be hammered into bars, and afterwards beat out into plates or leaves for different purposes of art. Like gold, it is insoluble in any acid, except a mixture of the muriatic and nitric.

It has lately been found in Russia in considerable quantities, and employed for the purposes of coin, for which it is well adapted.

Platinum and Oxygen.

(§ 219.) Considerable uncertainty exists with regard to the oxides of platinum. The metal cannot be made to combine with oxygen by the strongest heat of the best furnaces. When it has been dissolved in a mixture of muriatic and nitric acids, a precipitate may be formed by adding to the solution either soda or potash, which is said to be constituted of about 96 metal and 16 oxygen. It is the basis of the salts of this metal.

Platinum and Chlorine.

(§ 220.) Platinum does not take fire when introduced in thin leaves into chlorine, but it slowly combines with the gas, and is converted into a chloride. The chloride is also formed by its solution in the nitro-muriatic acid. The solution should be evaporated to dryness, and then digested with muriatic acid, which should also be driven off. The dry mass may then be cautiously heated nearly to redness. Being boiled with a considerable quantity of water, and, finally, dried, the mass is most probably a chloride of platinum.

It is of an olive colour, and destitute of taste and smell. It is infusible, and scarcely soluble in water. When heated to redness, the chlorine is driven off, and the pure metal remains. It is composed of about

	Parts
Platinum	96
Chlorine . .	36
	132

Platinum and Sulphur.

(§ 221.) Platinum and sulphur combine together, directly, by mixing equal weights of the two in an exhausted glass tube, and heating them together. The mass should be finally heated nearly to redness, to expel every thing volatile. The sulphuret thus formed is of a dull bluish-grey colour. It has no lustre, but when rubbed on paper it leaves a metallic stain. Its analysis nearly corresponds with the assumption that it is a compound of one equivalent of each ingredient, or

Platinum	96
Sulphur	16
	112

Palladium.—56.

(§ 222.) The four following metals were all first found amongst the grains of rough platinum, imported into this country from South America, and their discovery soon followed the establishment of that metal as a distinct species. Palladium resembles platinum in colour, except that it is a little duller. It is malleable and ductile, and its specific gravity is about 11.5. Its point of fusion

appears to be intermediate between those of platinum and gold. In hardness, it is superior to wrought iron. On exposure to a strong heat it tarnishes a little, but it becomes bright again upon increasing the temperature. It is acted upon by the nitric, nitrous, sulphuric, and muriatic acids, but is most readily soluble in the nitro-muriatic.

Palladium and Oxygen.

(§ 223.) Palladium is thrown down from its solution by potash in the state of an oxide of an orange colour, which is supposed to be a compound of

1 equivalent palladium	56
1 ditto oxygen	8
	64

and is the basis of its salts.

Palladium and Sulphur.

Sulphuret of Palladium.—72.

(1 P. 56 + 1 S. 16.)

(§ 224.) Although palladium requires such a strong heat for its fusion, if touched when hot with a piece of sulphur, it runs like lead. The sulphuret is whiter than the metal, but very brittle. It is composed of

1 equivalent palladium	56
1 ditto sulphur	16
	72

Rhodium.—44.?

(§ 225.) Rhodium has only been procured in very minute quantities, from the solutions of crude platinum, in the form of a black powder, which requires the strongest heat of a wind furnace for its fusion. When fused, it has a white colour and metallic lustre: it is hard, brittle, and its specific gravity is about 11. It is not acted upon by any acid or mixture of acids, except when alloyed with other metals, in combination with which, it may be dissolved by the nitro-muriatic acid. Its solution, when freed from the metals with which it is mixed, is of a rose colour (from whence it derives its name); and pure potash precipitates from it a yellow oxide, which is soluble in all the acids which have been tried.

Iridium and Osmium.

(§ 226.) When the crude platinum has been submitted to the action of nitro-muriatic acid, a part remains undissolved, in the form of a black powder, resembling plumbago, which consists of a mixture of the metals iridium and osmium. By alternate and frequent digestions in soda and muriatic acid the two may be separated.

Iridium is white, and has only once been fused, by the power of an immense galvanic battery, into a porous metallic globule, which possessed the high specific gravity of 18.6. It may readily be alloyed with other metals, and gold retains its colour and malleability, though mixed with a considerable proportion. Its most marked character is its extremely difficult solubility in acids.

(§ 227.) Osmium can only be obtained as a metal in a disintegrated state; as it is capable of supporting a white heat, without being volatilized or fused. It is of a dark-grey or blue colour. If ignited in open vessels, with access of air, it is oxidized, and then dissipated in vapour. On agitating the metal with mercury, an amalgam is formed, and with copper, silver, and gold, it forms malleable alloys.

The pure oxide is soluble in water and volatile. It emits a peculiar odour, which has something of the pungency of chlorine, from whence it derives its name*. The aqueous solution is colourless; and, when shaken with mercury, is decomposed, soon loses its smell, and forms an amalgam.

Nickel.—30.?

(§ 228.) There is a brittle reddish alloy, which is known in commerce by the name of *speiss*, which is chiefly a compound of nickel and arsenic; from which, by particular treatment, the former metal may be obtained in a state of purity. Its colour is white, and intermediate between those of silver and tin. When ignited, its colour changes to bronze. It will receive a very high polish, is very malleable, and may be forged, when hot, into bars; and when cold, may be hammered into plates, and drawn into fine wire. Its specific gravity is 8.5. It is attracted by the magnet, and is itself capable of having the magnetic power communicated to it. It is fusible with great difficulty. It suffers no change at common temperatures from either air or water; but by a long exposure to a red heat, with free access of air, it is converted into a brown oxide, which is still magnetic.

* From a Greek word, signifying odour.

Nickel and Oxygen.

(§ 229.) There is, probably, more than one oxide of nickel; but some uncertainty exists with regard to their constitution. The metal burns vividly, and throws out sparks in oxygen gas. It may also be precipitated, in the state of oxide, from its solution in nitric acid by potash. The protoxide is calculated to be composed of

1 equivalent of nickel	. .	30
1 ditto oxygen	.	8
		38

It is soluble in the acids, and also in ammonia, which latter property is made use of to separate it from iron. At a sufficiently high temperature all its oxides are reducible without addition.

Chapter VII.

On the Metals which absorb and retain Oxygen at high temperatures, but do not decompose water at any temperature.

Lead,	*Uranium,*
Tellurium,	*Antimony,*
Copper,	*Columbium,*
Bismuth,	*Tungsten,*
Titanium.	*Chromium,*
Cobalt,	*Molybdenum,*
Cerium,	*Arsenic,*

and their Binary compounds.

(§ 230.) The preceding division of the metals includes all those whose affinity for oxygen is so slight, that any connexion which they form with it is dissolved by the mere application of a high degree of temperature. We shall now proceed to examine those which absorb and retain oxygen at high temperatures, but whose affinity for that element is not sufficient to enable them to decompose water at any temperature. The list consists of fourteen, viz.—Lead, Tellurium, Copper, Bismuth, Titanium, Cobalt, Cerium, Uranium, Antimony, Columbium, Tungsten, Chromium, Molybdenum, and Arsenic.

Lead.—104.

(§ 231.) Lead is a common, useful, and well-known metal. When pure it has a bluish-white colour, and, when recently melted or cut, exhibits considerable lustre. It, however, very soon tarnishes. It is very soft and flexible. Its specific gravity is 11.3. It may be beaten into thin leaves, and drawn into wire. Its melting point is about 610° of Fahrenheit. It is very rarely indeed met with in nature in the metallic state; but the ore from which it is chiefly derived is a sulphuret.

Lead and Oxygen.

Protoxide of Lead.—112.

(1 L. 104 + 1 O. 8.)

(§ 232.) Lead absorbs oxygen quickly at high temperatures; and, when fused in open vessels, a grey film forms upon its surface, which is a mixture of the metal and protoxide. By continuing the heat it assumes a uniform yellow colour. In this state the protoxide is called, in commerce, *massicot;* and, when partially melted, the term *litharge* is applied to it. When thus obtained, however, it is always impure.

When a solution of lead in nitric acid is precipitated by potash, the dried powder is the protoxide in a state of purity. It has a yellow colour; is insoluble in water; fuses at a red heat; but in close vessels is unchangeable in the fire. It has been carefully determined to be a compound of

1 equivalent of lead	. .	104
1 ditto oxygen	.	8
		112

It constitutes the basis of the salts of lead.

Deutoxide of Lead.—232.

(2 L. 208 + 3 O. 24.)

(§ 233.) The deutoxide of lead may be obtained by exposing the protoxide or *massicot* to heat, with a large surface and free access of air. It is then converted into the well-known pigment *red lead* or *minium.* At a red heat it gives off this second dose of oxygen, and returns to the state of protoxide. It may be regarded as a compound of

2 equivalents of lead	. . .	208
3 ditto oxygen	. .	24
		232

The simple proportions of which are

1 equivalent of lead	. . . .	104
$1\frac{1}{2}$ ditto oxygen	.	12
		116

in which view the multiple of the oxygen of the first oxide, not being an entire number, would form an exception to the general law of chemical composition.

Peroxide of Lead.—120.

(1 L. 104 + 2 O. 16.)

(§ 234.) When the deutoxide of lead is digested with nitric acid, the greater part is reduced to the state of protoxide, and dissolved; but a dark brown powder remains insoluble, which is the peroxide. It is composed of

1 equivalent of lead	. .	104
2 ditto oxygen	.	16
		120

When strongly heated it gives off three or four per cent. of oxygen gas, and is converted into protoxide. By passing a stream of chlorine through red lead diffused in water, a solution is obtained, from which this peroxide may be precipitated, in abundance, by potash.

(§ 235.) The oxides of lead are easily vitrified, and have the property of combining with all the metals except gold, silver, and platinum, and those which are found peculiarly associated with the latter. Gold and silver may thus be purified by melting them with lead: the process is called *cupellation.* The metal to be purified is wrapped up in a sheet of lead, and laid upon a crucible made of some very porous substance: they melt together, the lead becomes first oxidated, then vitrified, and sinks into the *cupel,* carrying along with it all the baser metals, and leaving the gold or silver upon its surface.

Lead and Chlorine.

Chloride of Lead.—140.

(1 L. 104 + 1 C. 36.)

(§ 236.) When lead, in filings, is thrown into chlorine moderately warmed, the metal burns with a white flame, and throws off sparks. The combination, however, may more readily be produced for examination by adding some common salt to a solution of lead in nitric acid. The precipitate must be well washed in water, and dried.

The chloride of lead has a sweet taste, and is soluble in twenty-two parts of water at common temperatures. It is fusible at a heat below redness, and then assumes the appearance and consistence of horn, and has been called *horn lead.* It may also be volatilized by raising the heat. It is composed of

1 equivalent of lead	. .	104
1 ditto chlorine	.	36
		140

Lead and Sulphur.

Sulphuret of Lead.—120.

(1 L. 104 + 1 S. 16.

(§ 237.) Lead readily combines with sulphur, and forms a compound less fusible than the metal, and of a metallic lustre. It is found in nature; and, under the name of Galena, constitutes the most abundant ore from whence the metal is derived. The sulphuret consists of

1 equivalent of lead	. .	104
1 ditto sulphur	.	16
		120

Tellurium.—29.?

(§ 238.) Tellurium is a metal of small importance, found only in minute quantities in the gold mines of Transylvania. Its colour is between those of tin and lead: it has considerable lustre, and its fracture is scaly. It is very brittle, and melts at a temperature below ignition. It is the most volatile of all the metals except mercury, and may readily be distilled. Its vapour condenses into brilliant metallic drops. Its specific gravity is only 6.1.

Tellurium and Oxygen.

(§ 239.) Tellurium is oxidized when heated in contact with air, and burns with a sky-blue flame, edged with green. It gives off a grey smoke, of a pungent nauseous smell, which condenses into a white oxide. It is fusible and volatile at high temperatures. There are some doubts with regard to its analysis, but it is probably a compound of

1 equivalent of tellurium	.	29
1 ditto oxygen	. . .	8
		37

It combines both with acids and alkalies and other bases.

Tellurium and Hydrogen.

Telluretted Hydrogen Gas.

(§ 240.) Tellurium possesses the singular property of combining with hydrogen. The compound may be obtained by mixing together oxide of tellurium, hydrate of potash, and charcoal, at a red heat, and acting upon the mixture by dilute sulphuric acid. The product is gaseous, and must be received over mercury.

Telluretted hydrogen gas is soluble in

water, and forms a claret-coloured solution. It burns with a bluish flame, and deposits the oxide of the metal. Its smell is peculiar, but not unlike that of sulphuretted hydrogen. Like that compound it reddens litmus paper, and may be considered as a feeble acid.

Copper.—64.

(§ 241.) We are now arrived at the consideration of a metal as important to the service of man as the last has hitherto proved insignificant. The physical properties of copper are known to every one. It possesses a beautiful red colour, and considerable lustre. It has a peculiar smell when warmed or rubbed. Its specific gravity is about 8.8. It may be hammered into very thin leaves, and drawn into wire. Its melting point is very little below that of gold, being about 2548° of Fahrenheit's scale. By a more violent heat, it may be made to boil, and to evaporate in visible fumes. It is found in the metallic state in nature, but the great source of its supply is an ore in which the metal is found combined with sulphur.

Copper and Oxygen.

Protoxide of Copper.—72.

(1 C. 64+1 O. 8.)

(§ 242.) Copper tarnishes and rusts in the air by combining with its oxygen. The protoxide may be obtained by heating together to redness, in a close vessel, sixty-four parts of metallic copper with eighty parts of the peroxide, which we shall presently describe. When a plate of copper is exposed for some time to heat in contact with air, and afterwards hammered, it throws off scales, which are a mixture of metallic copper and peroxide; and, when treated as above directed, will also afford the protoxide.

It is of a red colour, and is composed of

1 equivalent of copper .	64
1 ditto oxgen . .	8
	72

It is often found native in beautiful red crystals.

It is dissolved by some of the acids, and also by ammonia.

Peroxide of Copper.—80.

(1 C. 64+2 O. 16.)

(§ 243.) The peroxide of copper is easily obtained pure by keeping the scales above described at a red heat exposed to air. It may also be procured by dissolving the metal in nitric acid, and adding potash; when an abundant precipitate will be formed, which must be sufficiently heated to drive off any water which it may contain. This oxide is a tasteless black powder, and is composed of

1 equivalent of copper . .	64
2 ditto oxygen . .	16
	80

It forms salts with the acids, and is also soluble in ammonia.

Copper and Chlorine.

Protochloride of Copper.—100.

(1 C. 64+Ch. 36.)

(§ 244.) When copper filings are introduced into chlorine they take fire, and two compounds of the elements are produced. One of these is the protochloride. It is a fixed yellowish substance, slightly transparent, not unlike rosin, and easily fused. It may be conveniently made by heating together two parts of the perchloride of mercury, and one of copper filings. It is insoluble in water. Muriatic acid dissolves it without effervescence, and water precipitates it unchanged. When heated to redness in close vessels, it remains fixed and unchanged, but in the open air it is dissipated with white fumes. It is composed of

1 equivalent of copper . .	64
1 ditto of chlorine . .	36
	100

Perchloride of Copper.—136.

(1 C. 64+2 Ch. 72.)

(§ 245.) The perchloride of copper is formed by the action of chlorine upon copper, at the same time as the protochloride. It sublimes in the state of a yellowish-brown powder. When exposed to the air, it absorbs moisture, and becomes first white, and then green. It is decomposed by heat, which converts it into protochloride, by driving off one proportion of chlorine. It is constituted of

1 equivalent of copper . .	64
2 ditto chlorine . . .	72
	136

Copper and Sulphur.

(§ 246.) The protosulphuret, and the persulphuret of copper, have been already described (§§ 21 and 22) for the purposes of illustration. It is unnecessary to add anything here to the description which we have given.

Bismuth.—71.

(§ 247.) Bismuth is a metal of a reddish white colour, whose fracture shows it to be composed of brilliant plates adhering together. Its specific gravity is 9.8. It is scarcely malleable, breaks under the hammer, and cannot be drawn into wire. It is very fusible, and melts at a temperature of 476° of Fahrenheit. It may be obtained in fine crystals by slow cooling, and may be completely volatilized at a high heat out of contact with the air. When melted in the air its surface becomes covered with a greenish-brown oxide.

Bismuth and Oxygen.

Oxide of Bismuth.—79.

(1 B. 71 + 1 O. 8.)

(§ 248.) Bismuth takes fire, and burns with a blue flame, when strongly heated with access of air, forming an oxide of a yellowish colour, known by the name of *flowers of Bismuth*. It is very fusible, and, like the oxides of lead, is converted by heat into glass. It has sometimes been employed for the purposes of cupellation (§ 235). It is constituted of

1 equivalent bismuth . .	71
1 ditto oxygen . . .	8
	79

It forms salts with the acids.

Bismuth and Chlorine.

Chloride of Bismuth.—107.

(1 B. 71 + 1 C. 36.)

(§ 249.) Bismuth, in a state of fine division, takes fire in chlorine, burns with a pale blue light, and is converted into a chloride. It is of a greyish-white colour, granular texture, and opaque. It is not sublimed by heat. Its analysis proves it to be composed of

1 equivalent of bismuth .	71
1 ditto chlorine . . .	36
	107

Alloys of Bismuth.

(§ 250.) Bismuth is capable of being alloyed with most metals, and forms, with some of them, compounds of remarkable fusibility. On this account it is much used for the composition of *soft solders*. A mixture of 8 parts of bismuth, 5 of lead, and 3 of tin, forms an alloy, which melts below the temperature at which water boils, and is known by the name of *fusible metal*.

Titanium.

(§ 251.) Titanium has only, till very recently, been found in small quantities in the state of an oxide, in a few rare minerals. It has probably never, but once, been completely reduced by art to the metallic state, the process being very difficult, and requiring a very high heat. It is described as of a dark copper colour, with much brilliancy, brittle, and, in small scales, possessing considerable elasticity. Very lately, the metal has been found in minute cubic crystals, in the slags taken from the bottom of the smelting furnaces of large iron-works. Their colour and lustre is like burnished copper; their specific gravity 5.3: and they are so hard, that they scratch a polished surface of rock-crystal. The metal is exceedingly infusible. It tarnishes in the air, and is easily oxidized by heat. Too little is known regarding this untractable substance to enable us to fix its equivalent.

Titanium and Oxygen.

(§ 252.) Titanium is probably susceptible of three degrees of oxidizement: the first oxide is blue, the second red, and the third white. The red oxide is found in nature in prismatic crystals; the white is the basis of its salts.

Cobalt.

(§ 253.) Cobalt is a brittle, somewhat soft, but difficultly fusible metal. Its colour is reddish-grey; it possesses little lustre; and its specific gravity is 8.6. It is attracted by the magnet, and is capable of becoming magnetic. It tarnishes by exposure to air. Its equivalent has not been fixed with certainty, owing to some discrepancy in the analysis of its compounds.

Cobalt and Oxygen.

(§ 254.) In a very intense heat, cobalt burns with a red flame.

An oxide may be formed by long exposure to a strong heat, with access of air: it is of a deep blue, approaching to black. It is probably a protoxide; and may also be formed by precipitating

the solution of the metal in nitric acid by potash. The precipitate is at first combined with water, and of a bright blue colour, but by drying assumes so dark a blue as to appear black.

When this oxide is exposed to the air it gradually absorbs a further dose of oxygen, and is converted into an olive green.

Both these oxides, by being heated in the air, pass to the state of peroxide, and become of a brown colour. The fine blue substance, known in commerce by the name of *zaffre*, is oxide of cobalt fused with sand or calcined flints. This, when finely ground and washed, is called *smalts*, and is much used for imparting a blue colour to linen, and for staining glass and china. All the salts of cobalt contain the protoxide.

Cerium.

(§ 255.) The only minerals which are known to contain the metal cerium are extremely rare, even in the cabinets of collectors; and the attempts to reduce the oxide to the metallic state have either failed or merely produced a small globule not larger than a pin's head. This metallic globule was harder, whiter, much more brittle, and more scaly in its fracture than cast iron.

It appears that there are two oxides of the metal: the protoxide is white, and the peroxide of a reddish colour. Both the oxides form salts with the acids.

Uranium.

(§ 256.) The ores of this metal are scarcely less rare than those of the preceding, and are nearly as difficult of reduction. It has, however, been obtained in the form of a metallic button, of the weight of 28 grains; of a dark grey colour, hard, and firmly cohering. On filing it, or rubbing it with another hard body, it exhibited a metallic lustre of an iron-grey colour. Its specific gravity has been found as high as 9.

There are, probably, two oxides of the metal: the protoxide, which is greyish-black; and the peroxide which is yellow.

The two oxides are employed in the arts; the first to give a black, the second, an orange colour, to porcelain.

Antimony.—44.

(§ 257.) Antimony, in its metallic state, is of a dusky-white colour, very brittle, and of a scaly texture. Its specific gravity is about 6.8. It melts at a heat of about 810° Fahrenheit, and crystallizes on cooling. Its surface tarnishes by exposure to the atmosphere, and when heated to whiteness, in a covered crucible, and suddenly exposed to the air, it burns with a white light. It is obtained for use from the native sulphuret.

Antimony and Oxygen.

Protoxide of Antimony.—52.

(1 A. 44 + 1 O. 8.)

(§ 258.) If to a solution of the well-known medicine called *tartar emetic*, we add a solution of pure ammonia, a protoxide of antimony will be precipitated, which should be washed with plenty of hot water. It is of a dirty-white colour, fuses at a red heat, and forms on cooling an opaque crystalline mass. It may be sublimed in close vessels by a strong heat. When exposed in open vessels, to a red heat, it absorbs a further dose of oxygen, and is converted into the deutoxide. It is composed of

1 equivalent of antimony	.	44
1 ditto oxygen	.	8
		52

It forms salts by combination with the acids.

Deutoxide of Antimony, or Antimonious Acid.—56.

(1 A. 44 + 1½ O. 12.)

(§ 259.) When antimony, or its protoxide, is strongly heated in open vessels, or when the metal is burnt in oxygen, the deutoxide is formed. It sublimes, and may be condensed on a cold surface in the form of needles of a silvery whiteness. It does not readily fuse, and is more volatile than the protoxide. It is quite insoluble in water, but possesses many of the properties of an acid, and enters into combination rather with alkalies than with acids. It is composed of

1 equivalent of antimony	.	44
1½ ditto oxygen	.	12
		56

(§ 260.) The composition of the deutoxide of antimony presents, when thus regarded, an exception to the general law of chemical composition, which

also occurs in two or three other metals, viz., that the multiple of the oxygen of the first oxide is $1\frac{1}{2}$, and not an entire number. The theoretical difficulty, however, may be removed by considering (as we have already done in the similar in ance of lead, § 233) this oxide as composed of two equivalents of the metal and three of oxygen (2 A. 88+3 O. 24), or as a compound of one equivalent of the *prot*oxide with one of the following or *per*oxide (52+60).

Peroxide of Antimony, or Antimonic Acid.—60.

(1 A. 44+2 O. 16.)

(§ 261.) The peroxide of antimony may be obtained, by dissolving the metal in nitromuriatic acid; from which it may be precipitated by throwing the solution into water, as it is insoluble in that fluid. When recently prepared it reddens litmus paper. It is thus obtained in the form of a white *hydrate;* but if exposed to a temperature not exceeding 600° Fahrenheit, the water is driven off, and pure peroxide remains, of a yellow colour. When exposed to a red heat it parts with a portion of its oxygen, and is converted into the deutoxide. It enters into definite combinations with alkalies, and not with acids, and hence it ranks with the latter class of bodies.

Antimony and Chlorine.

Protochloride of Antimony.—80.

(1 A. 44+1 C. 36.)

(§ 262.) When powdered antimony is thrown into chlorine, combustion ensues, and the protochloride is formed by the union of the two. It may also be produced by distilling a mixture of antimony with twice and a half its weight of bichloride of mercury. The chloride of antimony being very volatile, passes over into the receiver, and metallic mercury remains in the retort. At common temperatures it is a soft solid, which liquifies at a gentle heat, and was formerly called butter of antimony. It deliquesces on exposure to the air.

Bichloride of Antimony.—116.

(1 A. 44 + 2 C. 72.)

(§ 263.) By passing dry chlorine gas over heated metallic antimony, a transparent volatile fluid is obtained, which emits fumes on exposure to the air. It contains twice as much chlorine as the protochloride.

Antimony and Sulphur.

Sulphuret of Antimony.—60.

(1 A. 44 + 1 S. 16.)

(§ 264.) Antimony readily combines with sulphur, and forms a grey sulphuret with metallic lustre. The same compound is found in nature. It may be melted in close vessels without undergoing any change; but, when slowly roasted in a shallow vessel, it gradually loses sulphur and attracts oxygen, and may then be melted into a glassy substance, transparent at the edges, and called *glass of antimony.* It consists of eight parts of protoxide, and one of sulphuret.

Alloys of Antimony.

(§ 265.) Antimony may be made to combine with most of the metals. A very slight admixture of it, not exceeding $\frac{1}{2000}$th of the mass, is sufficient to destroy the ductility of gold, and even its fumes alone will produce that effect. When mixed with lead, in the proportion of one part in four, it composes the metal for printers' types.

Columbium.—144.

(§ 266.) This and the succeeding species furnish further instances of highly refractory metals extracted with great difficulty from very rare minerals, whose discovery and examination have afforded exercise for the highest talents, but which have not hitherto been applied to any use in the arts.

The colour of columbium is iron-grey, and, when scratched with a knife, it shows the metallic lustre. It has only been obtained in agglutinated particles by an intense heat, the specific gravity of which was 5.6. It is not acted upon by nitric or muriatic acids, or by a mixture of the two.

Columbium and Oxygen.

Oxide of Columbium, or Columbic Acid.—162.

1 C. 144 + 1 O. 8.)

(§ 267.) The only oxide of columbium known possesses the properties of an acid, and forms definite compounds with alkalies rather than with acids. It is found in nature in combination with oxide of iron. When purified, it is of a white colour, and, when laid upon wet litmus paper, it converts the blue colour to a red. It is tasteless, and insoluble in water. It does not acquire any

colour by exposure to a high temperature with access of air. It is believed to be a compound of

1 equivalent of columbium	.	144
ditto oxygen	. .	8
		152

Its specific gravity is 6.5.

Tungsten.—96.

(§ 268.) Tungsten has a greyish-white colour, like that of iron, but is not magnetic. Its specific gravity is 17.2. It is extremely hard and brittle, and fusible with great difficulty. It is oxidized by the action of heat and air.

Tungsten and Oxygen.

Protoxide of Tungsten.—112.

(1 T. 96 + 2 O. 16.)

(§ 269.) When hydrogen gas is passed over tungstic acid (which will be immediately described) at a red heat, it is converted into a dark-brown oxide, in which the oxygen is to that in the acid as 2 to 3. When heated in the air it burns like tinder, and is reconverted into the acid.

Tungstic Acid.—120.

(1 T. 96 + 3 O. 24.)

(§ 270.) Tungstic acid is a compound of three equivalents of oxygen and one of tungsten. It is of a yellow colour, insoluble in water, and has no effect upon the blue colour of litmus. It forms definite compounds with the alkalies. Its specific gravity is 6.1.

Chromium.—28.

(§ 271.) Chromium is a rare metal, and is extracted from only two minerals; in one of which it is combined, as an acid, with lead, and in the other, as an oxide, with iron. It requires a violent heat for its reduction. It has merely been obtained as a porous mass of agglutinated grains. It is very brittle, of a greyish-white, intermediate between tin and steel. Its specific gravity is 5.9.

Chromium and Oxygen.

Protoxide of Chromium.—36.

(1 C. 28 + 1 O. 8.)

(§ 272.) It is probable that chromium forms two oxides by union with oxygen, besides the acid which will be presently described. The protoxide may be obtained by heating a salt called chromate of mercury to redness. The mercury is thus dissipated in vapour, and at the same time the chromic acid is resolved into oxygen and the protoxide of chromium. It is of a green colour; insoluble in water; infusible; and suffers no change from the exposure to heat. It is probably a compound of

1 equivalent of chromium	. .	28
1 ditto oxygen	. . .	8
		36

It is soluble in the acids. It is employed in the arts to give a beautiful green colour to porcelain, and is the colouring principle of the emerald.

Deutoxide of Chromium.—44.

(1 C. 28 + 2 O. 16.)

(§ 273.) The deutoxide is of a brown colour, and may be formed by exposing a solution of the protoxide in nitric acid to a heat just sufficient to decompose the acid. Very little is known concerning it. It does not enter into combination with the acids.

Chromic Acid.—52.

(1 C. 28 + 3 O. 24.)

(§ 274.) The chromic acid is found in nature in combination with lead, and may be extracted by boiling the powdered mineral with twice its weight of carbonate of potash, and afterwards saturating the alkali by a mineral acid. It is of a red colour, and may be obtained, from its solution, in ruby-coloured crystals. It has a sour metallic taste. When exposed to heat it gives off oxygen, and is converted into the protoxide. It is probably constituted of

1 equivalent of chromium	. .	28
3 ditto oxygen	. . .	24
		52

It gives its colour to the ruby.

Molybdenum.—48.

(§ 275.) Molybdenum has never been reduced into masses of any considerable magnitude, but has only been obtained in small globules, in a blackish brilliant mass. It is grey, brittle, and very infusible. Its specific gravity is 8.6. It is found in nature in the state of sulphuret, and united as an acid with lead. Both are very rare minerals.

Molybdenum and Oxygen.

Molybdous Acid.—64.

(1 M. 48 + 2 O. 16.)

(§ 276.) The molybd*ous* acid may be formed by triturating together one part of molybdenum with two parts of molybd*ic* acid, presently to be described, with a little hot water. By evaporating the solution thus formed, at a temperature not exceeding 120° Fah., the acid is obtained in the form of a fine blue powder. It reddens vegetable blues, and combines with alkaline bases. It consists of about 100 metal and 34 parts oxygen.

Molybdic Acid.—72.

(1 M. 48 + 3 O. 24.)

(§ 277.) The native sulphuret of molybdenum, being roasted for some time, may be reduced to fine powder, and dissolved in liquid ammonia. When nitric acid is added to the solution, the molybdic acid is precipitated in white scales, which become yellow upon melting or subliming them. It changes the vegetable blues to red, and has a sharp metallic taste. It is sparingly soluble in water; and paper dipped in the solution, becomes, when dried in the sun, of a beautiful blue. When the metal is heated with access of air, it absorbs oxygen, and is converted into the acid.

Arsenic.—38.?

(§ 278.) The substance commonly met with under the name of arsenic is an oxide, from which the metal may be obtained by mixing it with oil, and subliming at a low red heat in a clean Florence flask. The arsenic will thus be reduced, and will be found lining the neck of the flask in a state of metallic brilliancy, not unlike polished steel. It is very brittle, and may be reduced to powder by pounding in a mortar. Its specific gravity is 8.3. It is readily fusible and volatilized. It may be collected, unchanged, in close vessels; but if thrown on red hot iron, it burns with a blue flame and white smoke; it emits also a strong smell of garlic, which belongs to it in its metallic state, and not to its oxides. Arsenic is speedily tarnished by exposure to air, and converted into a black powder, which is a mixture of the metal and oxide.

Arsenic and Oxygen.

Arsenious Acid.—54.

(1 A. 38 + 2 O. 16.)

(§ 279.) Arsenious acid, or white oxide of arsenic, is white, semi-transparent, and brittle. It has a faintly-sweet taste, and is well-known to be highly poisonous. It is volatilized at a temperature of 380° Fah.; but, if suddenly heated may be melted into a kind of glass. It is sparingly soluble in water, and more so in hot than in cold. It reddens vegetable blue colours. There is some uncertainty with regard to the analysis of this compound, and indeed with regard to the other combinations of arsenic, so that its equivalent cannot be said to be absolutely determined. It is probably constituted of

1 equivalent of arsenic	-	38
2 ditto oxygen	-	16
		54

Arsenic Acid.—62.

(1 A. 38 + 3 O. 24.)

(§ 280.) Another compound of arsenic and oxygen may be formed by boiling one part of arsenious acid to dryness in six parts of nitric acid. Nitric oxide is given off, and a white, concrete substance remains, which is the arsenic acid. It has a sour, metallic taste; reddens vegetable blues, and attracts moisture from the air. When its solution is evaporated it assumes the consistence of jelly, but does not crystallize. It is a very active poison. It may be melted into a glass which is deliquescent; and, at a very strong red heat, it is converted into arsenious acid and oxygen. It is probably composed of

1 equivalent of arsenic	-	38
3 ditto oxygen	-	24
		62

Arsenic and Hydrogen.

Arseniuretted Hydrogen.

(§ 281.) Arsenic combines with hydrogen, and forms a very poisonous compound; to his researches on which, one eminent chemist owed his death. It may be formed by melting together, in a covered crucible, three parts of granulated tin and one part of metallic arsenic in powder, and submitting the alloy, in fragments, to the action of muriatic acid in a glass retort. On the application of a moderate heat a gas is given off, which may be collected over the water bath. It is colourless, without acid properties, and its specific gravity is about 0.5. It extinguishes combustible bodies,

but burns with a blue flame. Its smell resembles that of garlic, but is more fetid. It instantly destroys small animals which are immersed in it. Its composition has not been accurately determined, but it is believed that the hydrogen exists in it in a condensed state; for it deposits arsenic, and is expanded in volume at high temperatures.

Arsenic and Sulphur.

(§ 282.) Arsenic combines with sulphur in two proportions, and both the sulphurets are found native. The compound with the least proportion of sulphur is red, and known in commerce by the name of *realgar;* that with the greatest proportion is of a bright yellow, and is named *orpiment.* The sulphur exists in the two in the proportion of 2 to 3. They have both been employed in calico-printing and dyeing.

Chapter VIII.

On the Metals which absorb and retain Oxygen at high temperatures, and decompose Water at a red heat.

Tin, Iron, Zinc, Cadmium, Manganese, and their Binary Compounds.

(§ 283.) Pursuing the plan which we have laid down, we come now to a class of metals whose affinity for oxygen is such that they not only absorb oxygen from the atmosphere, and retain it at a high temperature, but abstract it also from water, when assisted by a heat not below redness. This list consists only of five—Tin, Iron, Zinc, Cadmium, and Manganese.

Tin.—59.

(§ 284.) Tin is a well-known metal; but the substance which is popularly so called consists of sheets of iron merely plated with it. It is a silvery-white metal, which, by exposure to the air, acquires a slight, superficial tarnish. It is very soft; and, when bent backwards and forwards, occasions a peculiar crackling noise. It is very malleable, and its specific gravity is about 7.9. It melts at a temperature of 442° Fah. It is chiefly found, in nature, in the state of oxide, which constitutes the ore from which it is obtained for commerce.

Tin and Oxygen.

Protoxide of Tin.—67.

(T. 59+1 O. 8.)

(§ 285.) When tin is kept for a long time melted in contact with the air, it absorbs oxygen, and is converted into a grey powder. This protoxide may also be obtained by pouring nitric acid, diluted with ten times its bulk of water, upon tin filings, and leaving them in contact forty-eight hours. It should be carefully dried without being exposed to the air. This oxide has such a strong affinity for a further dose of oxygen, that, when heated to redness in open vessels, it is converted into peroxide with evolution of heat and light. It will be hereafter seen that it carries this avidity for oxygen with it into most of its combinations. It is composed of

1 equivalent of tin	- - -	59
1 ditto oxygen	-	8
		67

This oxide is soluble in the acids and in ammonia; and the ammoniacal solution, when long kept, deposits metallic tin in crystals, and becomes a solution of peroxide.

Peroxide of Tin.—75.

(1 T. 59+2 O. 16.)

(§ 286.) The peroxide may be obtained either by heating the protoxide, as we have just stated, or by the action of nitric acid, slightly diluted, upon the metal. A white powder is produced; which is a hydrate of the peroxide, from which the water may be expelled by a red heat. The peroxide of tin is of a straw-yellow colour. It is insoluble in all the acids, except the muriatic, but unites feebly with the alkaline bases. It is constituted of

1 equivalent of tin	- - -	59
2 ditto oxygen	-	16
		75

Tin and Chlorine.

Protochloride of Tin.—95.

(1 T. 59+1 C. 36.)

(§ 287.) The protochloride of tin may be formed by heating together an amalgam of tin and mercury with the protochloride of mercury (calomel). It is a grey, semi-transparent, crystalline solid. It is soluble in water, and forms a solution which rapidly attracts oxygen from the air, and deposits peroxide of tin. Its analysis shows it to be composed of

1 equivalent of tin	- - -	59
1 ditto chlorine	-	36
		95

Perchloride of Tin.—131.

(1 T. 59+2 C. 72.)

(§ 288.) Tin, in a state of fine division, may be burnt in chlorine; when a volatile, clear liquid is formed. This perchloride may also be produced by heating together tin filings and perchloride of mercury. It has the property of inflaming oil of turpentine when suddenly poured into that fluid. It emits white fumes when exposed to the air, from its great attraction for its moisture. When mixed with a little water, it is converted into a solid crystalline substance. It is composed of

1 equivalent of tin		- - -	59
2	ditto	chlorine -	72
			131

Tin and Sulphur.

(§ 289.) There are two sulphurets of tin. The proto-sulphuret may be formed by fusing together tin and sulphur. It is of a bluish colour, lamellated texture, and brittle. It is composed of one equivalent of each of its ingredients. The bi-sulphuret may be made by heating together, in close vessels, the peroxide of tin and sulphur. It is produced in fine flakes of a beautiful gold colour, and was formerly known by the name of *Mosaic gold.* It is composed of

1 equivalent of tin		- - -	59
2	ditto	sulphur -	32
			91

It is used as a pigment for giving a gold colour to some works of art.

Alloys of Tin.

(§ 290.) The alloys of tin with copper in various proportions, form *bronze, bell-metal,* or *gun-metal:* and, when the proportion of the first is about one-third, the alloy is beautifully white, and used for the reflectors of telescopes.

Iron.—28.

(§ 291.) Iron is at once the most diffused, the most abundant, and the most important of the metals. It is found in all the three kingdoms of nature: its ores constitute almost mountains; and there is scarcely an art which could exist, in any perfection, without it. It has a bluish-white colour, and is susceptible of a very high polish. It is very malleable, and is capable of being drawn into very fine wire, though not of being beaten into very thin leaves. Its specific gravity is about 7.7. It is one of the most infusible of the metals; but this disadvantage is counterbalanced, for all practical purposes, by its possessing the property of welding (§ 218) in high perfection. Cast iron, or iron in that state in which it is first run from its ores, and which is very far from pure, has been found to melt at a temperature equal to about 3479° of Fahrenheit's scale; but the fusing point of the pure metal is, doubtless, higher. At common temperatures it is exceedingly hard; but, when heated to redness, very soft and ductile. It is attracted by the magnet, and capable of having the magnetic virtue imparted to it. It is, very rarely, found native in the metallic state; in masses which are, with great probability, supposed to be of meteoric origin. The ores from which its supply is chiefly derived are oxides of the metal.

Iron and Oxygen.

Protoxide of Iron.—36.

(1 I. 28 + 1 O. 8.)

(§ 292.) The affinity of iron for oxygen is very great. We have already seen that it may be burned in oxygen gas (§ 39); and, when heated to redness in the open air, it absorbs oxygen rapidly, and is converted into black scales, called the *black oxide* of iron. This is, however, not a definite compound, but a mixture of protoxide and peroxide. The same compound is also produced when the steam of water is brought into contact with red hot iron (§ 47).

The protoxide of iron may be obtained pure by passing dry hydrogen gas over the peroxide at a temperature a little below redness. Its colour is a very dark blue. It is attracted by the magnet, but not so strongly as the metal itself. It is very combustible; and, when thoroughly exposed to the air at common temperatures, it spontaneously ignites, and becomes converted into the peroxide. All its combinations are also characterised by this high attraction for oxygen. It is composed of

1 equivalent of iron		- -	28
1	ditto	oxygen -	8
			36

Peroxide of Iron.—40.

(1 I. 28 + $1\frac{1}{2}$ O. 12.)

(§ 293.) When iron is dissolved in

nitric acid, then boiled for some time, precipitated by ammonia, and exposed to a low red heat, it is converted into peroxide. It is of a red colour, and not attracted by the magnet. It is composed of

1 equivalent of iron	- -	28
$1\frac{1}{2}$ ditto oxygen	-	12
		40

and presents another instance of the anomaly to which we have before referred (§ 260), namely, that the oxygen of the peroxide is not a multiple, by a whole number, of that of the protoxide. Both the oxides of iron constitute salifiable bases.

Iron and Chlorine.—64.

Proto-chloride of Iron.

(1 I. 28+1 C. 36.)

(§ 294.) When iron is dissolved in diluted muriatic acid, a green solution is obtained, which should be evaporated to dryness, and ignited out of the contact of the air. The product has a grey colour, a metallic splendour, and a lamellar texture. This proto-chloride is a fixed substance, and requires a red heat for its fusion. There are some doubts attending the results of its anaysis.

Perchloride of Iron.—82.

(1 I. 28 + $1\frac{1}{2}$ C. 54.)

§ 295.) When iron wire is burned in chlorine, a bright yellowish-brown substance is obtained, of a high degree of lustre, which is volatile at a temperature a little above 212° Fah., and crystallizes in the form of small iridescent plates. It is composed of

1 equivalent of iron	- -	28
$1\frac{1}{2}$ ditto chlorine	-	54
		82

and exhibits the same anomaly of the half-equivalent as the peroxide. They may each be considered, in a theoretical point of view as before suggested (§ 260), as composed of two equivalents of the metal with three of their other respective ingredients, and the present instance may be represented as 2 I. 56 + 3 C. 105, the same proportions being thus preserved.

Iron and Sulphur.

Proto-sulphuret of Iron.—44.

(1 I. 28 + 1 S. 16.)

(§ 296.) The best method of forming the proto-sulphuret of iron is to take a bar of the metal at a glowing red heat and rub it well with a roll of sulphur: the compound will fall down in drops. It is distinguished by being attracted by the magnet, and is sometimes found in nature. It is composed of

1 equivalent of iron	- -	28
1 ditto sulphur	-	16
		44

Bisulphuret of Iron.—60.

(1 I. 28 + 2 S. 32.)

(§ 297.) The bisulphuret cannot be artificially formed, but is an abundant natural product, and has received the name of *iron pyrites.* It is of a bronze yellow colour, and is often found in crystals. When heated to redness it loses half its sulphur, and becomes converted into the proto-sulphuret. It is not attracted by the magnet. It is composed of

1 equivalent of iron	- -	28
2 ditto sulphur	-	32
		60

Iron and Carbon.

Steel.

(§ 298.) Iron, as it flows from the furnaces in which it is reduced, in which state it is called cast iron, contains, amongst other ingredients, a very considerable, but variable proportion of carbon, amounting sometimes to $\frac{1}{40}$th of its weight. In this state it is neither ductile nor malleable, but very brittle.

If the purest malleable iron be surrounded by charcoal in powder, and exposed to a long-continued red heat, it unites with about $\frac{1}{150}$th of its weight of carbon, and acquires new properties, being converted into steel: it becomes much harder, more sonorous and elastic, and takes a much higher polish. When ignited and suddenly cooled, it is rendered so hard and brittle as to be unfit for any useful purpose. To fit it for use it requires what is termed *tempering;* which consists in heating it up to a certain point, that varies with the purpose to which it is afterwards to be applied. These points are, to a certain extent, indicated by the various colours which the metal assumes on its surface.

The experiment has often been tried of inclosing small diamonds in cavities in soft iron, and igniting the mass;

when the former disappear, and the inner surface of the latter is found is converted into steel (§ 151).

Steel may be distinguished from pure iron by applying a drop of any weak acid to its surface, when the charcoal which it contains will be exhibited by a black stain.

Plumbago.

(§ 299.) THE well-known substance of which black-lead pencils are made is a true *carburet* of iron, containing about 10 per cent. of the metal and 90 of pure carbon. It is a natural product of considerable value, and has not hitherto been formed by art.

ALLOYS OF IRON.

(§ 300.) IRON may be alloyed with various metals; but the most useful combination of this nature is that with tin. Iron plates, previously cleaned by a weak acid, and dipped into that metal when melted, become perfectly plated with it, and are very extensively employed in the arts.

ZINC.—34.

(§ 301.) ZINC is known in commerce by the name of *spelter;* but usually contains an admixture of lead and sulphur. When purified from these, it is of a brilliant white colour, inclining to blue. Its specific gravity is about 6.8. Under particular circumstances of temperature, it is malleable, and may be beaten into leaves or drawn into wire. It melts at about 725° of Fahrenheit's scale, and crystallizes on cooling. It is easily volatilized, and may be purified by distillation.

ZINC AND OXYGEN.

Oxide of Zinc.—42.

(1 Z. 34 + 1 O. 8.)

(§ 302.) WHEN zinc is exposed to a temperature in the air very little above its melting point, it burns with a dazzling flame, of a bluish tint; and its oxide flies up in the form of white flowers, formerly called *flowers of zinc*, or *philosophical wool.* This oxide, which is the only one known, is, however, fixed in the fire, and may be melted into a clear yellow glass. The same oxide is formed when the vapour of water is brought into contact with the metal in a state of ignition. This decomposition takes place with great rapidity. The oxide is composed of

1 equivalent of zinc	- -	34
1 ditto oxygen	-	8
		42

It constitutes a salifiable base.

ZINC AND CHLORINE.

Chloride of Zinc.—70.

(1 Z. 34 + 1 C. 36.)

(§ 303.) WHEN zinc is burned in chlorine, a solid, grey, semi-transparent substance is formed, which is the only known chloride of that metal. It is as soft as wax, and melts at a temperature a little above 212° Fah. It rises in vapour at a heat below ignition. Its taste is intensely acrid, and it corrodes the skin. It dissolves in water, with the evolution of much heat. It may also be procured by heating together zinc filings and bichloride of mercury (corrosive sublimate). Its analysis, though not exact, agrees sufficiently with the assumption that it is a compound of

1 equivalent of zinc	- -	34
1 ditto chlorine	-	36
		70

ALLOYS OF ZINC.

(§ 304.) ZINC is capable of being alloyed with many of the metals. It forms particularly useful compounds with copper, which, in different proportions, are known by the names of *brass*, *pinchbeck*, *Dutch gold*, *Prince Rupert's metal*, &c.

CADMIUM.—56.

(§ 305.) CADMIUM has only been very lately discovered amongst the ores of zinc, and has chiefly been derived from a sublimate which rises before that metal in the process for obtaining it by distillation. It resembles tin very nearly in colour, lustre, and the crackling sound which it yields when bent. It is harder and more tenacious than that metal. It may be drawn into fine wire, and reduced into thin plates. Its specific gravity is about 8.6. It melts at a temperature below redness, and is volatilized almost as readily as mercury. Its vapour condenses in drops, which have a crystalline appearance when cold.

CADMIUM AND OXYGEN.

Oxide of Cadmium.—64.

(1 C. 56 + 1 O. 8.)

(§ 306.) CADMIUM is little altered

exposure to the air at common temperatures, but, when heated in open vessels, it burns and flies off in smoke, which falls and forms a very fixed oxide of a brownish-yellow colour. It is insoluble in water, and is the only known compound of the metal with oxygen. It is constituted of

1 equivalent of cadmium	- -	56
1 ditto oxygen	- - -	8
		64

It is soluble in the acids.

Manganese.—28 ?

(§ 307.) Manganese is never found native in the metallic state, the substance commonly known in the arts by that name being an impure oxide. The metal is extremely refractory, and more difficult of fusion even than iron. It is of a dusky-white colour, but bright and shining in its fracture. Its specific gravity is about 8.0. It is very brittle, soon tarnishes on exposure to the air, and crumbles into a brown powder.

Manganese and Oxygen.

Protoxide of Manganese.—36.

(1 M. 28 + 1 O 8.)

(§ 308.) Considerable uncertainty still exists with regard to the various compounds of manganese with oxygen. The protoxide may be formed by mixing the deutoxide (presently to be described) with charcoal, and exposing it to a strong red heat; or by passing a current of hydrogen over the same oxide heated to redness in a porcelain tube. When pure it is of a green colour, but speedily becomes brown from the absorption of oxygen. It may also be produced by dissolving the common black oxide of manganese in sulphuric or nitric acid, adding a little sugar, and precipitating, by solution of potash; a white powder may be thus collected, which is a hydrate, and which being heated to redness out of the contact of air, gives off its water, and yields the oxide. It takes fire when gently heated, and is converted into the deutoxide.

Deutoxide of Manganese.—40.

(1 M. 28 + $1\frac{1}{2}$ O. 12.)

(§ 309.) The deutoxide of manganese is readily procured by exposing the peroxide to a low red heat. It is of a brown colour. It presents the anomaly of an equivalent and a half of oxygen united to the metal. When exposed to the air it slowly absorbs oxygen, and returns to the state of peroxide. Both these oxides form the bases of saline compounds.

Peroxide of Manganese.—44.

(1 M. 28 + 2 O. 16.)

(§ 310.) This compound is found native in abundance, and is used in the arts for discolouring glass, and for the manufacture of chlorine for bleaching. It is commonly of an earthy appearance, and mixed with other ingredients; but it is not unfrequently met with in crystals of a black colour and metallic lustre. It undergoes no change on exposure to the air. It is insoluble in water, and does not unite either with acids or alkalies. It has the singular property of inflaming linseed oil, when previously well dried and kneaded with it. On exposure to red heat it gives out oxygen (§ 36), and is converted, as above stated, into deutoxide.

Manganeseous and Manganesic Acids.

(§ 311.) There is reason to suppose that manganese unites with additional proportions of oxygen, and forms two distinct acids; but the subject requires further investigation before it can be considered as finally determined. When the peroxide of manganese is mixed with an equal weight of nitre, and exposed to a red heat, a green-coloured mass is obtained, which has long been known by the name of *mineral chameleon*. On dissolving this substance in water, a green solution is obtained; the colour of which soon changes in succession to blue, purple, and red, and ultimately disappears entirely. The experiment may be varied by putting equal quantities of this substance into two glass vessels, and pouring into the one hot, and into the other cold water. The hot solution will have a beautiful green colour, and the cold a deep purple. The shades will vary as the temperature alters. These green and red colours have been ascribed to the successive formation of the two acids.

CHAPTER IX.

On the Metals which absorb and retain Oxygen at high temperatures, and decompose Water at common temperatures, or the ALKALINE METALS,

Potassium,	*Calcium,*
Sodium,	*Barium,*
Lithium,	*Strontium,*

and their Binary compounds.

(§ 312.) WE come now to those metals whose attraction for oxygen is of the most intense degree; which absorb it from the atmosphere, retain it at the highest heats, and detach it from water even at common temperatures. Their oxides had, for ages, resisted all attempts to analyse them, when at length they were found to yield to the decomposing energy of the voltaic pile. The secret of their composition being once developed, some of them have been since reduced by other means; but the majority can only yet have their prevailing affinity temporally suspended by the electric repulsion. There is a striking resemblance between the properties of the oxides of all these metals; they are emphatically denominated *alkalies.* Their taste is hot, bitter, and caustic: they are more or less soluble in water: they change the colours of vegetable blues to green, and yellows to brown; characters which correspond with those which we have described as existing in the volatile alkali, ammonia (§ 79).

POTASSIUM.—40.

(§ 313.) IF a thin piece of hydrate of potash, slightly moistened, be placed between two plates of platinum connected with the extremities of a voltaic apparatus of 200 double plates, four inches square, it will soon undergo fusion; oxygen will separate at the positive pole, and small metallic globules will appear at the negative surface. The metal can only thus be obtained in very small quantities, but quite sufficient to determine its characters. After this important discovery was made, it was found that the same decomposition might be effected by the power of elective affinity, assisted by strong heat, and the metal be produced in much greater abundance. If iron-turnings be heated to whiteness in a curved gun-barrel, and potash melted and made slowly to come in contact with the turnings, the air being carefully excluded, potassium will be formed and collect in the part of the tube kept cool for that purpose.

This extraordinary metal is solid at the ordinary temperature of the atmosphere; but it is soft, and easily moulded by the fingers. In colour and lustre, when newly cut, it exactly resembles mercury. It is perfectly opaque, and a good conductor both of heat and electricity. It is lighter than water; its specific gravity, at 60°, being 0.865. It is not perfectly fluid till its temperature reaches 150° Fah.; and it may be sublimed at a red heat, provided the air be perfectly excluded. When heated in the air it burns with a white flame; and, when thrown upon water, it acts upon that fluid with great violence, swimming upon its surface, and burning with great splendour. It oxidizes rapidly in the air, and can only be preserved under naphtha or other light fluids, into the composition of which oxygen does not enter, or in glass tubes hermetically sealed.

POTASSIUM AND OXYGEN.

Protoxide of Potassium, or Potash.—48.
(1 P. 40 + 1 O. 8.)

(§ 314.) THE protoxide of potassium, commonly called potash, is always formed when potassium is put into water, or exposed to dry air or oxygen gas. By the first process, even when the solution is evaporated to dryness, and exposed to a red heat, it retains a proportion of water; by the second it is anhydrous. The anhydrous oxide may also be obtained by decomposing nitrate of potash (nitre), at a red heat, in a vessel of gold. In this state it is white, extremely caustic, and fusible a little above a red heat. It has an intense affinity for water, which it absorbs from the air. When once combined with it, it cannot be wholly expelled by the most intense heat. The solid hydrate of potash is composed of

1 equivalent of potash	-	48
1 ditto water	- -	9
		57

It is in this state that it is commonly met with. It is easy to ascertain the quantity of oxygen which enters into the composition of potash by the volume of hydrogen liberated during the action of potassium on water; for, when the metal is plunged at once under that fluid, it is oxidized without the evolution of light and heat; and each grain de-

taches 1.06 cubic inch of hydrogen gas. Hence 75 parts of potassium condense 15 parts of oxygen to become potash, and 15 : 75 :: 8 : 40; therefore potash is constituted of

1 equivalent of potassium	- -	40
1 ditto oxygen	- -	8
		48

The potash of commerce is obtained, in an impure state, by the incineration of vegetable matters, and hence is designated as the *vegetable* alkali. The purest is distinguished by the name of *pearlash.* To render it perfectly pure for chemical purposes, *pearlash* should be dissolved in twice its weight of boiling water: an equal weight of fresh burned lime, reduced to a powder by slaking, must then be equally diffused through it, and the whole boiled and stirred in an iron vessel for half an hour. The clear solution, carefully separated from the sediment, must next be evaporated to dryness in a silver dish. Pure alcohol will now take up only the perfectly pure hydrate of potash, which may be obtained in the solid form by evaporating or distilling off the spirit in silver vessels. The hydrate of potash has an intensely acrid taste, and destroys the texture of animal and vegetable substances. It changes blue vegetable colours to green, and neutralizes acids without effervescence. It rapidly attracts moisture and carbonic acid from the air. It is extensively used in several manufactures.

Peroxide of Potassium.—64.

(1 P. 40 + 3 O. 24.)

(§ 315.) When potassium is burned in the open air, or in oxygen gas, it is converted into an orange-coloured substance, which is the peroxide of the metal. It may likewise be formed by passing a current of oxygen over potash at a red heat. When this peroxide is thrown into water, a solution of potash (or protoxide) is formed, and oxygen is given off with effervescence. It is composed of

1 equivalent potassium	40
3 ditto oxygen	24
	64

When it is fused, and brought into contact with combustible bodies, they burn vividly in the excess of its oxygen.

Potassium and Chlorine.

Chloride of Potassium.—76.

(1 P. 40. + 1 C. 36.)

(§ 316.) When small pieces of potassium are introduced into chlorine, the inflammation is very intense. Each grain absorbs 1.1 cubic inch of the gas, and the white saline body which is formed, is constituted of

1 equivalent potassium	40
1 ditto chlorine	36
	76

Chloride of potassium is soluble in water, and crystallizes from its solution by evaporation. It has a bitter, disagreeable taste.

The attraction of chlorine for potassium is stronger than that of oxygen: for both the oxides are decomposed by that body; the chloride being produced and oxygen extricated.

Alloys of Potassium.

(§ 317.) Potassium combines rapidly with mercury; and the union is effected by merely bringing the two metals in contact at the temperature of the air. The amalgam is soft and malleable; but its solidity and brittleness increase with the proportion of potassium. This compound may be obtained by a very easy process by those who possess a voltaic pile of only twenty plates. A thin stratum of mercury is made to cover the bottom of a flat glass dish, of about two inches diameter: this is covered with a strong solution of pure potash; an iron wire must connect the negative pole of the battery with the mercury, and a platinum wire from the positive pole must dip into the alkaline solution within about a line of the surface of the mercury. With such an arrangement, more than 1200 grains of mercury will become solid in twenty-four hours.

The amalgam rapidly attracts oxygen from the air; and the mercury is restored to its former state. It has the property of dissolving all the metals, and even of acting upon platinum.

Potassium unites also with gold, silver, and copper; and when the alloys are thrown into water, they are decomposed, a solution of potash is formed, and the metals are separated unaltered.

Sodium.—24.

(§ 318.) Sodium may be obtained by exactly the same electrical and chemical processes as potassium, by acting upon

pure hydrate of soda. It requires, however, a stronger voltaic power, and a higher degree of heat to effect the decomposition. The metal is as white as silver, possesses great lustre, and is a good conductor of heat and electricity. It is very malleable, and perfectly opaque. It is lighter than water; its specific gravity being 0.972. It is less fusible than potassium, not becoming perfectly liquid till it acquires a temperature between 180° and 190° F. When exposed to the atmosphere, it tarnishes; but is not changed in air that has been artificially dried. When thrown upon water, it produces a violent effervescence and hissing noise, but does not inflame. It gradually diminishes with great agitation; a solution of soda is produced, and hydrogen escapes. When heated to its fusing point in air, or oxygen gas, it becomes rapidly oxidated; but does not inflame till nearly red hot, when it burns with a white light, accompanied with red sparks. Like potassium, it is best preserved under the surface of pure naphtha.

Sodium and Oxygen.

Protoxide of Sodium, or Soda.—32.

(1 S. 24 + 1 O. 8.)

(§ 319.) The protoxide of sodium, or soda, is formed when the metal is burned in perfectly dry atmospheric air. It is also formed when sodium is thrown into water, and its composition may be determined by the quantity of hydrogen which is liberated. Upon evaporating, the solution, however, obtained by the last means, the soda is obtained in the form of a *hydrate*, from which the last portions of water cannot be expelled by any degree of heat. It is composed of

1 equivalent oxide	32
1 ditto water	9
	41

the oxide itself being a compound of

1 equivalent of sodium	24
1 ditto oxygen	8
making the equivalent of soda	32

The solid hydrate is easily fusible by heat, and extremely caustic; it is soluble in water and alcohol, and possesses all the alkaline properties in an eminent degree. It is found in commerce in an impure state, and is largely used in many important manufactures. It may be purified by a similar process to that for obtaining pure potash. Under the name of *natron*, it is found native in mineral seams or crusts, and hence has been called the *mineral* alkali. It is also largely produced by the incineration of sea-weeds.

Peroxide of Sodium.—40.

(1 S. 24 + 2 O. 16.)

(§ 320.) When Sodium is strongly heated in an excess of pure oxygen, an orange-coloured substance is formed, which is the peroxide of the metal. It is very fusible, and a non-conductor of electricity. When acted upon by water, it gives off oxygen and forms a solution of soda. It deflagrates when heated with combustible bodies. It is constituted of

1 equivalent of sodium - -	24
2 ditto oxygen - -	16
	40

Sodium and Chlorine.

Chloride of Sodium, or Common Salt.—60.

(1 S. 24 + 1 C. 36.)

(§ 321.) Sodium burns in chlorine, and is converted into a white compound, having all the characters of the well-known substance *common salt.* The same product may also be formed by heating the metal in muriatic acid gas, when hydrogen is liberated and the chloride formed. It is an abundant product of nature, and is become a necessary ingredient of the food of man, and of essential utility in many of the arts. It is soluble in water, and crystallizes from its solution when the water is evaporated. It fuses, but does not undergo any other change from a strong heat. The attraction of sodium for chlorine is not so strong as that of potassium: hence, when the latter metal and common salt are heated together, sodium is obtained. The chloride of sodium is composed of

1 equivalent of sodium - -	24
1 ditto chlorine - -	36
and the equivalent of common salt is	60

Lithium.—10.

(§ 322.) Lithium has very lately been discovered in the state of an oxide or alkali in two or three rare minerals; and in this respect offers a strong contrast to the abundant distribution of the vegetable and mineral alkalies which we have just been describing It has

been reduced to the metallic state by the power of the voltaic battery; but it burned again so rapidly, that it was only observed to be of a white colour, and much to resemble sodium.

Lithium and Oxygen.

Lithia.—18.

(1 L. 10 + 1 O. 8.)

(§ 323.) Pure oxide of lithium, or lithia, has a very sharp, burning taste, and rapidly corrodes the cuticle, like potash. It is soluble in water with the evolution of heat, but very sparingly soluble in alcohol. It strongly possesses all the alkaline properties. When heated in contact with platinum, it fuses, and acts upon the metal. If exposed to the air, it does not deliquesce, but rapidly attracts carbonic acid. It is composed of

1 equivalent of lithium		- -	10
1 ditto	oxygen	- -	8
and the equivalent of lithia is		-	18

Calcium.—20.

(§ 324.) Calcium has only hitherto been obtained in minute quantities by the power of electrical repulsion, acting upon lime; which has by these means been proved to be an oxide of the metal. The process may be repeated, with a battery of sufficient power, by forming some pure lime into a paste with water, and placing a globule of mercury in a small cavity in its surface. It may be placed upon a metallic plate connected with the positive wire of the battery; while the negative wire is made to dip into the mercury. When the process has been continued sufficiently long, an amalgam of calcium is obtained, which may be put into a small retort with naphtha enough to cover it. Upon applying heat the naphtha first rises in vapour, then the mercury, and the calcium remains fixed. It has been obtained in such small quantities, that but little is known of its nature. The metal is white, with the colour and lustre of silver. When gently heated in air, it takes fire, and burns with an intense white light into lime. When the amalgam of calcium is thrown into water, hydrogen is given off, and a solution of lime is formed.

Calcium and Oxygen.

Protoxide of Calcium, or Lime.—28.

(1 C. 20+1 O. 8.)

(§ 325.) From the quantity of hydrogen evolved by the action of calcium upon water, it has been calculated that lime is composed of

1 equivalent of calcium		- -	20
1 ditto	oxygen	- -	8
making the equivalent of lime		-	28

Lime is a well-known and highly-important substance, whose compounds are widely distributed in all the kingdoms of nature. When pure, in which state it may be obtained by exposing white marble, or calcareous spar to a strong red heat, it is a soft white substance of the specific gravity of 2.3. It is perfectly fixed in the fire, and requires an intense heat for its fusion; but it remarkably promotes the fusion of earthy bodies, and is therefore used in metallurgy as a powerful *flux*. Its taste is caustic, alkaline, and astringent. It is sparingly soluble in water, requiring at 60° Fah. 750 times its weight to effect the solution. It is rather less soluble in hot than in cold water; so that when lime-water is boiled, the lime is precipitated. It renders vegetable blue colours green, and yellows brown. Lime absorbs moisture from the air, and becomes converted into a hydrate, which is also formed when *quick lime* (as it is commonly called) undergoes the process of *slaking*. This consists in sprinkling it with water, which it greedily absorbs; giving out, at the same time, a great quantity of heat. The hydrate is a white bulky powder, which consists of

1 equivalent of lime		- -	28
1 ditto	water	- -	9
			37

It parts with its water at a red heat.

Deutoxide of Calcium.—36.

(1 C. 20+2 O. 16.)

(§ 326.) By passing oxygen gas over ignited lime, the gas is absorbed, and a peroxide of calcium formed, which is believed to be composed of

1 equivalent of calcium		- -	20
2 ditto	oxygen	- -	16
			36

Calcium and Chlorine.

Chloride of Calcium.—56.

(1 C. 20+1 Ch. 36.)

(§ 327.) The chloride of calcium has not been directly made, on account of the great scarcity of the metal; but when pure lime is heated in chlorine, the

oxygen is evolved and the chloride produced: It is composed of

1 equivalent of calcium	- -	20
1 ditto chlorine	- -	36
		56

When it is exposed to the air, it deliquiates rapidly; and the solution is of a thick oily consistence, and of a bitter acrid taste. Its attraction for moisture is so great, that it is very commonly employed in chemical experiments, for drying gases, and other products (§ 84 and 174), by passing them over its surface. It may be crystallized, and when mixed in this state with new-fallen snow, a degree of cold may be produced sufficient to freeze mercury.

Barium.—70.

(§ 328.) Barium has been obtained in small quantities, by a process exactly similar to that for obtaining calcium, the paste being formed of a mineral, called *Carbonate of Barytes*. The residue of the distillation in this case is a dark-grey metal, whose lustre is inferior to that of cast-iron. It fuses at a heat below redness; and if heated to redness, is converted into vapour, which acts violently upon glass. From some experiments which have been made upon it, it is probably four or five times heavier than water. When exposed to the air, it falls into a white powder, which is the protoxide of the metal; and when thrown into water, it acts with great violence, producing hydrogen gas, and a solution of the oxide. When heated in the air, it combines with its oxygen more rapidly, burning with a deep-red light.

Barium and Oxygen.

*Protoxide of Barium, or Baryta.**—78.

(1 B. 70 + 108.)

(§ 329.) The oxide formed, as above, by the combustion of metallic Barium, may more readily be obtained by the combination, at an intense heat, of *carbonate of baryta* mixed with charcoal. This salt is a native product, and may also be prepared by art. The more simple operation, however, is to dissolve the carbonate in nitric acid, and then to decompose the nitrate; which may be effected by a moderate heat.

Baryta, when pure, has a sharp caustic taste; changes vegetable blue colours to green, and neutralizes the acids. It is poisonous, as are all its soluble compounds. It is generally obtained in the form of a grey powder of the specific gravity of about 4. It is insoluble in pure alcohol, but has a very strong affinity for water. It may be *slaked* in the manner of *quick-lime*, but with the evolution of a much greater degree of heat. The *hydrate* thus formed is composed of

1 equivalent of baryta	-	78
1 ditto water	-	9
		87

It melts at a red heat, but does not part with its water at the highest temperature of a smith's forge. It dissolves in twice its weight of boiling water, and in 20 parts of water at the temperature of 60° Fah. The boiling solution, upon cooling, deposits regular crystals, which consist of

1 equivalent of barytes	-	78
20 ditto water	-	180
		258

19 of which are driven off by a red heat. They communicate a yellowish colour to the flame of alcohol. The protoxide is composed of

1 equivalent of barium	-	70
1 ditto oxygen	-	8
		78

Peroxide of Barium.—86.

(1 B. 70 + 2 O. 16.)

(§ 330.) Barium may be made to unite with a further proportion of oxygen. When pure barytes is ignited in oxygen the gas is rapidly absorbed, and a grey compound formed. It is best prepared by passing a current of dry oxygen over the oxide placed in a glass tube horizontally fixed in a furnace, and heated to redness. It is composed of

1 equivalent of barium	-	70
2 ditto oxygen	-	16
		86

(§ 331.) It is from this compound that the *oxygenized water*, before described (§ 54.), is prepared. When acted upon by liquid muriatic acid it abandons part of its oxygen, and is reduced to the state of protoxide; which is dissolved by the acid, while the oxygen unites with the water. Sulphuric acid carefully added

* From a Greek word, signifying *heavy*, from its great specific gravity.

to this solution forms an insoluble precipitate with the barytes, and the muriatic acid is again set free; which is thus made to act upon successive portions of the peroxide, until the water is fully saturated with oxygen. The muriatic acid is then removed by dropping in some sulphate of silver; when another insoluble precipitate falls down and the remaining sulphuric acid is abstracted by a solution of pure barytes. The perfect success of this process, though simple in theory, depends upon many practical precautions, and must be carried on in vessels surrounded with ice.

Barium and Chlorine.

Chloride of Barium.—106.

(1 B. 70 + 1 C. 36.)

(§ 332.) When pure baryta is heated in chlorine, oxygen gas is liberated, and a chloride of barium formed—which is composed of

1 equivalent of barium	-	70
1 ditto chlorine	-	36
		106

Strontium.—44.

(§ 333.) Strontium may be obtained, in minute quantities, by the same process as barium; substituting the carbonate of strontia,* which is a native product, for the carbonate of baryta. It resembles barium, is fusible with difficulty, and not volatile. It decomposes water with the evolution of hydrogen, and is converted into an oxide by exposure to the air.

Strontium and Oxygen.

Protoxide of Strontium, or Strontia.—52.

(1 S. 44 + 1 O. 8.)

(§ 334.) The protoxide of strontium, or strontia, may be obtained by exposing nitrate of strontia to a strong red heat. It is a grey substance which possesses distinct alkaline properties. It may be slaked with water, which causes an intense heat. The solid hydrate is composed of

1 equivalent of strontia	-	52
1 ditto water	-	9
		61

* So called from Strontian in Scotland, where it was first discovered.

and strontia of

1 equivalent of strontium		44
1 ditto oxygen	-	8
		52

The hydrate fuses at a red heat; but its water cannot be driven off by the strongest temperature of a blast furnace. It is very soluble in boiling water, which deposits it in crystals, upon being allowed to cool undisturbed, which are composed of one equivalent of the oxide, and twelve of water. They are insoluble in alcohol, but impart a blood red colour to its flame.

It differs from baryta in not being poisonous: but its taste is acrid.

Chapter X.

On the Metals which are generally analogous to those of the last class, but whose Oxides are insoluble in water, and insipid: or the

Earthy Metals.

Magnesium. Yttrium. Aluminum. Glucinum. Zirconium.

(§ 335.) The existence of the remaining class of metals rests, for the most part, upon imperfect results of experiment, but upon strong analogy. Their oxides, in which form only they exist in nature, have long been known by the general name of *earths:* they are not convertible to the metallic state by any of the ordinary methods of reduction, and scarcely even by the utmost exertion of scientific refinements: they are insipid, and destitute of the acrid taste of the alkalies, but constitute salifiable bases and perfectly neutralize the acids. These earthy metals have been called Magnesium, Glucinum, Yttrium, Aluminum, and Zirconium.

Magnesium.—12.?

(§ 336.) By exposing *Magnesia*, in contact with mercury, for a long time to the influence of a powerful voltaic battery, an amalgam may be obtained; which, by distillation out of the contact of the atmosphere, affords a dark grey metallic film. It has been collected in such very minute quantities, as scarcely to suffice for determining its properties. It is, however, infusible at a very high temperature, but burns with a red light, and is converted into a white powder possessing the properties of magnesia. When thrown into water, it sinks to the bottom, effervesces slowly, and becomes covered with the same white substance.

Magnesium and Oxygen.

Oxide of Magnesium or Magnesia.—20.
(1 M. 12 + 1 O. 8.)

(§ 337.) The proportion in which the metallic base of magnesia combines with oxygen has not been determined by direct experiment; but it is inferred from the combinations of the oxide, that magnesia is a compound of

1 equivalent of magnesium	12
1 ditto oxygen -	8
and that its combining proportion is - - -	20

Pure magnesia may be obtained by exposing carbonate of magnesia to a strong red heat; and is commonly to be met with under the name of calcined magnesia. It is well known as a much-used medicine. It is a white, soft powder, having a specific gravity of 2.3. It is infusible, and possesses neither taste nor smell. It renders the colour of violets green when suspended in water; but is so insoluble, that if the water with which it has been mixed be afterwards filtered, it no longer affects blue vegetable colours. It absorbs a quantity of that fluid with the production of heat, and is converted into a hydrate. The water may, however, be again expelled by a red heat. Magnesia is abundantly distributed by nature in the mineral kingdom, entering largely into the composition of extensive rock formations; and also forms a considerable proportion of the ingredients of sea water, from which it is chiefly obtained for the purposes of commerce.

Glucinum.—20 ?

(§ 338.) By heating a peculiar earth called glucina,* with potassium, the latter has been converted into potash; and dark coloured particles, possessing a metallic lustre, were disseminated through the mass, which regained the earthy appearance by being heated in the air, and by the action of water. Hence it is probable that the earth is a compound of oxygen and a peculiar metal to which the name of glucinum has been given.

Oxide of Glucinum, or Glucina.—28.

(§339.) Glucina has been ascertained to exist only in three rare minerals, viz. the beryl, the emerald, and the euclase. It has been separated from the other ingredients with which it is combined, in the form of a fine, white, soft powder. It has the property of adhering to the tongue like pure clay. Its specific gravity is about 3. It has no action upon vegetable colours, and is insoluble in water, with which however it may be formed into a ductile paste. It is soluble in liquid potash or soda, but not in a solution of ammonia; it is, on the other hand, completely taken up by carbonate of ammonia, and is precipitated from it by boiling. This latter property distinguishes it from the other earths with which it might be liable to be confounded. It combines with the different acids, forming salts which possess a sweet astringent taste.

Yttrium.—34 ?

(§ 340.) The evidence of the metallic existence of yttrium is of the same nature, and obtained by the same means as that of the last species.

Oxide of Yttrium, or Yttria.—42.

(§ 341.) Yttria is a peculiar earth of still more rare occurrence even than glucine, having been chiefly found in a very scarce mineral from Ytterby in Sweden, whence it derives its name. When separated from its other associates in the compound, it is perfectly white, and very ponderous, its specific gravity being 4.8. It is devoid of taste and smell, and is smooth to the touch. It is insoluble in water, and infusible except at a very intense heat. It is not acted upon by pure alkalies, but is slightly soluble in carbonate of ammonia. It forms combinations with most of the acids.

Aluminum.—10 ?

(§ 342.) Till very lately, the evidence of the existence of the metallic base of alumine (or pure clay) was of the same imperfect nature as that of the other earths which we have just enumerated: the skilful application of the powers of elective attraction has, however, very recently effected its decomposition in a more satisfactory way. For this purpose dry chloride of aluminum (presently to be described) is put into a platina crucible with about a tenth of its weight of potassium, and the mixture gently heated over a spirit lamp, and afterwards allowed to cool gradually. The chlorine passes to the potassium and leaves the aluminum. Upon throwing the mass into water the metal falls to the bottom of the vessel in a granular

* From a Greek word signifying *sweet*: many of its combinations having a sweet taste.

state, like gunpowder. It possesses a metallic lustre, approaching to that of tin. When the powder is rubbed upon any hard substance with a burnisher, the particles adhere together and form a surface which strongly reflects the light. It has a powerful affinity for oxygen, but is not readily altered by exposure to either air or water at common temperatures. When heated in oxygen gas it burns with great splendour, and the evolution of intense heat which is sufficient to partially fuse the alumine, or oxide, which is formed, and which is one of the most infusible substances in nature. Aluminum is perfectly fixed at the highest temperatures to which it has been possible to expose it.

Aluminum and Oxygen.

Oxide of Aluminum, or Alumine.—18?

(1 A. 10 + 1 O. 8.)

(§ 343.) The oxide of aluminum, or alumine, is most abundantly distributed in the mineral kingdom of nature. It is found nearly in a state of purity in the precious gems, the ruby and the sapphire; and is a constituent of the oldest rocks and the most recent alluvial deposition. The different kinds of clay, of which porcelain, pipes, and bricks are made, consist of the hydrate of alumine in various degrees of purity. It may be obtained free from the admixture of other earths, for chemical purposes, by precipitating a solution of alum in water, by ammonia or the carbonates of the fixed alkalies; a white, bulky, hydrate of alumine is thus obtained, which, when carefully washed, and heated to whiteness, affords the pure anhydrous earth.

Pure alumine has neither taste nor smell; and does not affect the colours of vegetables. It is not soluble in water, but when moistened with that fluid, forms with it a cohesive ductile mass. It has a strong affinity for moisture, and after ignition greedily absorbs it from the atmosphere, to the amount of half its weight. It is capable of combining both with the fixed alkalies, and with acids, but is very sparingly taken up by the volatile alkali, and not by the alkaline carbonates.

It forms permanent combinations with the colouring matter of different organic substances, and is much used in the processes of dyeing and calico printing.

Aluminum and Chlorine.

Chloride of Aluminum, 46?

(1 A. 10 + 1 C. 36.)

(§ 344.) Chloride of aluminum may be produced by the direct combination of its two ingredients. It may be more easily procured by calcining pure alumine intimately mixed up with sugar and oil, and passing chlorine over the mixture at a red heat. The charcoal of the sugar and the oil abstracts the oxygen of the alumine, and carbonic oxide is formed: the aluminum at the same time unites with the chlorine. The chloride of aluminum is a yellow substance, which rises in vapour at a temperature of 212°. It attracts moisture rapidly from the air and deliquesces. The solution is sensibly acid.

Zirconium.

(§ 345.) The metallic base of zirconia (a very rare product of nature) has been lately disengaged by heating potassium with a salt called *fluate of zirconia and potash* carefully dried. The decomposition is effected at a temperature below redness. The residue, after washing in boiling water, and digestion in diluted muriatic acid, is pure zirconium.

It is thus obtained in the form of a black powder. When heated in the open air, it takes fire at a temperature below redness, burns very brightly, and is converted into the earth. When rubbed between two hard surfaces, it assumes the form of shining scales of a dark grey colour.

Oxide of Zirconium, or Zirconia.

(§ 346.) The oxide of zirconium has only been detected in two or three rare minerals (the zircon of Ceylon, and the hyacinth from France.) It is an earthy substance, much resembling alumine in external character. It has neither taste nor smell, and is quite insoluble in water. Its colour is white, and its specific gravity about 4.3. It forms salts with the different acids, and is sparingly dissolved by the alkaline carbonates, but not by pure alkalies.

(§ 347.) Having now completed the list of the metals, we shall subjoin two tables, similar to those of the non-metallic elements, which may assist in recalling their arrangement, and fixing upon the mind the equivalent proportions in which they are disposed to combine.

TABLE III.

METALLIC ELEMENTS.

	Electro-Negative.		Electro-Positive.	No. of Equivalents.
Oxides reducible by mere heat. (*Noble Metals.*)	. .		Mercury . . .	200
	. .		Silver	110
	. .		Gold	200
	. .		Platinum . . .	96
	. .		Palladium . .	56
	. .		Rhodium . . .	44
	. .		Iridium . . .	?
	. .		Osmium . . .	?
	. .		Nickel . . .	30
Do not decompose water at any temperature.	. .		Lead	104
	. .		Tellurium . .	29
	. .		Copper . . .	64
	. .		Bismuth . .	71
	. .		Titanium . . .	?
	. .		Cobalt . . .	?
	. .		Cerium . . .	?
	. .		Uranium . .	?
	. .		Antimony . . .	44
	. .		Columbium .	144
	. .		Tungsten . . .	96
	. .		Chromium . .	28
	. .		Molybdenum . .	48
	. .		Arsenic . . .	38
Decompose water at a red heat . .	. .		Tin	59
	. .		Iron	28
	. .		Zinc	34
	. .		Cadmium . .	56
	. .		Manganese . .	28
Decompose water at atmospheric temperatures. Oxides caustic. . . . (*Alkaline Metals.*)	. .		Potassium . .	40
	. .		Sodium . . .	24
	. .		Lithium . . .	10
	. .		Calcium . . .	20
	. .		Barium . . .	70
	. .		Strontium . .	44
Decompose water below a red heat, but oxides insipid . . (*Earthy Metals.*)	. .		Magnesium . .	12
	. .		Glucinum . .	20
	. .		Yttrium . . .	34
	. .		Aluminum . .	10
	. .		Zirconium . . .	?

TABLE IV.—Binary Compounds of Metallic Elements.

Equivalents.		Equivalents.		Acid. *Electro-Negative.*	No. of Equivalents.	Alkaline, or Basic. *Electro-Positive.*	No of Equivalents.	Neutral.	No. of Equivalents.
1	Mercury	+1	Oxy.	. . .		Protox. of Merc.	208		
	Ditto	+2	Ditto	. . .		Perox. of Merc.	216		
	Ditto	+1	Chlo.	. . .		. . .		Protochl. of Mercu. (*Calomel.*)	236
	Ditto	+2	Ditto	. . .		. . .		Bichlo. of Mercury (*Corrosive Sublimate.*)	272
	Ditto	+1	Sulph.	. . .		. . .		Protosulph. of Mer.	216
	Ditto	+2	Ditto	. . .		. . .		Bisulphu. of Mer.	232
1	Silver	+1	Oxy.	. . .		Oxide of Silver	118		
	Ditto	+1	Chlo.	. . .		. . .		Chloride of Silver	146
	Ditto	+1	Sulph.	. . .		. . .		Sulphuret of Silver	126
1	Gold	+3	Oxy.	. . .		Oxide of Gold .	224		
	Ditto	+3	Sulph.	. . .		. . .		Sulphuret of Gold	248
1	Platinum	+2	Oxy.	. . .		Oxide of Platin.	112		
	Ditto	+1	Chlo.	. . .		. . .		Chlo. of Platinum	132
1	Palladium	+1	Oxy.	. . .		Oxide of Palladium	64		
	Ditto	+1	Sulph.	. . .		. . .		Sulph. of Palladium	72
1	Nickel	+1	Oxy.	. . .		Oxide of Nickel .	38		
1	Lead	+1	Ditto	. . .		Protox. of Lead	112		
	Ditto	+1½	Ditto	. . .		. . .		Deutoxide of Lead	116
	Ditto	+3	Ditto	. . .		. . .		Peroxide of Lead	120
	Ditto	+1	Chlo.	. . .		. . .		Chloride of Lead	140
	Ditto	+1	Sulph.	. . .		. . .		Sulphuret of Lead	120
1	Tellurium	+1	Oxy.	. . .		Ox. of Tellurium	37		
1	Copper	+1	Ditto	. . .		Protox. of Copper	72		
	Ditto	+2	Ditto	. . .		Perox. of Copper	80		
	Ditto	+1	Chlo.	. . .		. . .		Protoch. of Copper	100
	Ditto	+2	Ditto	. . .		. . .		Perchlo. of Copper	136
1	Bismuth	+1	Oxy.	. . .		Oxide of Bismuth	79		
	Ditto	+1	Chlo.	. . .		. . .		Chlo. of Bismuth	107
1	Cobalt	+1	Oxy.	. . .		Oxide of Cobalt	?		
1	Antimony	+1	Ditto	. . .		Protox. of Antimo.	52		
	Ditto	+1½	Ditto	Antimonious acid	56				
	Ditto	+3	Ditto	Antimonic acid	60				
1	Columbium	+1	Ditto	Columbic acid	162				
1	Tungsten	+2	Ditto	. . .		. . .		Oxide of Tungsten	112
	Ditto	+3	Ditto	Tungstic acid	120				
1	Chromium	+1	Ditto	. . .		Protox. of Chromi.	36		
	Ditto	+2	Ditto	. . .		. . .		Deutox. of Chromi.	44
	Ditto	+3	Ditto	Chromic acid	52				
1	Molybdenum	+2	Ditto	Molybdous acid	64				
	Ditto	+3	Ditto	Molybdic acid	72				
1	Arsenic	+2	Ditto	Arsenious acid	54				
	Ditto	+3	Ditto	Arsenic acid .	62				
1	Tin	+1	Ditto	. . .		Protox. of Tin	67		
	Ditto	+2	Ditto	. . .		. . .		Peroxide of Tin .	75
	Ditto	+1	Chlo.	. . .		. . .		Protochlo. of Tin	95
	Ditto	+2	Ditto	. . .		. . .		Perchloride of Tin	131
1	Iron	+1	Oxy.	. . .		Protox. of Iron	36		
	Ditto	+1½	Ditto	. . .		Perox. of Iron	40		
	Ditto	+1	Chlo.	. . .		. . .		Protochlo. of Iron	64
	Ditto	+2	Ditto	. . .		. . .		Perchloride of Iron	82
	Ditto	+1	Sulph.	. . .		. . .		Protosulphu. of Iron	44
	Ditto	+2	Ditto	. . .		. . .		Bisulphuret of Iron	60
1	Zinc	+1	Oxy.	. . .		Oxide of Zinc .	42		
1	Cadmium	+1	Ditto	. . .		Ox. of Cadmium	64		
1	Manganese	+1	Ditto	. . .		Protox. of Manga.	36		
	Ditto	+1½	Ditto	. . .		Deutox. of Manga.	40		
	Ditto	+2	Ditto	. . .		. . .		Perox. of Manganese	44
1	Potassium	+1	Ditto	. . .		Potash . .	48		
	Ditto	+3	Ditto	. . .		. . .		Perox. of Potassium	64
	Ditto	+1	Chlo.	. . .		. . .		Chlo. of Potassium	76
1	Sodium	+1	Oxy.	. . .		Soda . .	32		
	Ditto	+2	Ditto	. . .		. . .		Perox. of Sodium	40

Equivalents.		Equivalents.		ACID. Electro-Negative.	No. of Equivalents.	ALKALINE, or BASIC. Electro-Positive.	No. of Equivalents.	NEUTRAL.	No. of Equivalents.
	Sodium .	+1	Chlo.	. . .		. . .		Chloride of Sodium (*Common Salt*)	60
1	Lithium .	+1	Oxy.	. . .		Lithia . .	18		
1	Calcium .	+1	Ditto	. . .		Lime . .	28		
	Ditto	+2	Ditto	. . .		. . .		Perox. of Calcium	36
	Ditto	+1	Chlo.	. . .		. . .		Chloride of Calcium	56
1	Barium .	+1	Oxy.	. . .		Baryta . .	78		
	Ditto	+2	Ditto	. . .		. . .		Perox. of Barium	86
	Ditto	+1	Chlo.	. . .		. . .		Chloride of Barium	106
1	Strontium	+1	Oxy.	. . .		Strontia . .	52		
1	Magnesium	+1	Ditto	. . .		Magnesia . .	20		
1	Glucinum	+1	Ditto	. . .		Glucina . .	28		
1	Yttrium .	+1	Ditto	. . .		Yttria . .	42		
1	Aluminum	+1	Ditto	. . .		Alumine . .	18		
	Ditto	+1	Chlo.	. . .		. . .		Chlo. of Aluminum	46
1	Zirconium	+1	Oxy.	. . .		Zirconia . .	?		

In Table III. it may be observed that all the metals are arranged on the electro-positive side; as in their decomposition by electric repulsion, their compounds are invariably reduced at the negative pole of the voltaic battery.

In Table IV. we may remark that the great majority of active combinations (or those compounds which are disposed to enter into further combination, and which are, almost without exception, those of oxygen) also stand in the electro-positive column; whereas in Table II. of the binary combinations of the non-metallic elements all but one are arranged on the electro-negative side. In the former we have a list of 9 acids and 33 *salifiable bases*, and in the latter of 22 acids and 1 base.

Amongst the combinations of oxygen with the metals it is worthy of observation, that there are many instances in which one proportion of oxygen constitutes a base, while a second with the same substance forms an acid. Sometimes one dose of this highly electro-negative element is not sufficient to neutralize the electro-positive energy of the metal, but leaves it as a base in the electro-positive class, while a second completely saturates it, and takes away all further power of combination: at other times, as with chromium, one proportion leaves a decided positive energy, a second completely neutralizes, and a third communicates a negative power.

We must here, however, recal to mind that this division of bodies into electro-negative and electro-positive, is not absolute but relative (§ 33.), and therefore some of the less electro-positive of the electro-positive class are capable of forming combinations with others of the bases: in this manner, ammonia will unite with several of the metallic oxides, and, more rarely, the fixed alkalies.

The column of the neutral compounds is necessarily very incomplete, as we have only described enough of that class to exemplify the subject: our purpose rather requiring that we should set before the student those substances which again enter into combination, than those in which chemical affinity is neutralized. The binary compounds of iodine, bromine, sulphur, &c. with all the metals, and their multiple proportions, would form an almost interminable list, many of which have never been examined or described, which it would not be consistent with our limits further to pursue.

CHAPTER XI.

On Fluorine and its Compounds.

(§ 348.) WE have stated (§ 98.) that "the class of electro-negative elements contains only four known and one hypothetical (conjectural) body, the existence of which requires to be established by further proof." The properties of the former, viz. oxygen, chlorine, bromine, and iodine, we have already described. We shall now adduce the evidence upon which *fluorine* is added to the list and describe the compounds into which it is believed to enter.

Hydro-Fluoric Acid.—19 ?

(1 F. 18 + 1 H. 1.) ?

(§ 349.) THERE is a substance well known in mining districts, called *fluor*

*spar**. It is found crystallized in cubes of various colours, green, yellow, and purple; and a compact variety of the same substance, the product of Derbyshire, is worked into splendid ornamental vases. If this mineral be redued to powder, mixed with twice its weight of strong hydro-sulphuric acid, and subjected to distillation, a powerful and highly corrosive liquid acid may be obtained. For this purpose a leaden or silver retort and receiver must be employed; and while a moderate heat is applied to the former, the latter must be kept cool by pounded ice or snow. The hydro-fluoric acid thus formed must be preserved in silver or leaden bottles, with stoppers of the same materials. It is extremely volatile, and not easily confined. In appearance it resembles oil of vitriol. Its specific gravity, when first prepared, is 1.06, but is increased by the gradual addition of water to 1.25; and there is no known instance of a similar condensation. It is necessary to use great caution in experimenting with this substance, as its vapours are highly irritating, and, when applied to the skin, it disorganises it so rapidly as to occasion dangerous ulcers. In addition to the usual properties of a powerful acid it acts strongly on glass, and corrodes it deeply. Plates of glass, covered with a composition of bees-wax and turpentine, may be drawn upon with a graver, and those parts which are laid bare may be perfectly etched by exposure either to the vapour or the diluted acid.

When brought into contact with potassium, a violent detonation takes place; *hydrogen gas escapes*, and a solid, white saline substance is formed, which may be called the *fluoride of potassium*, from analogy to the *chlorides*.

If lime be thrown into it, violent heat is extricated, water is given off, and the same substance as fluor spar or *fluoride of calcium* is produced. Attempts have been made to effect the decomposition of the fluoric acid, both upon the supposition that it may be a compound of an electro-positive body, such as sulphur, with oxygen; or that it is constituted of a highly electro-negative element, like chlorine, in union with hydrogen. The latter view is, of the two, the best supported by experiment and analogy.

When exposed to the agency of the voltaic pile, a disengagement of a small quantity of inflammable gas took place at the negative pole while the wire of the opposite end became corroded, and covered with a chocolate-coloured powder, which has been supposed to be a compound of fluorine and platinum. It is argued that in this experiment the acid was decomposed; that the inflammable gas at the negative pole of the battery was hydrogen, and that the unknown element, upon its disengagement at the positive pole, immediately combined with the platinum. The result, however, cannot be considered as decisive, in as much as fluorine was not obtained in an insulated form; and from the noxious vapours which arose during the process, it was impossible to examine the products with that attention which the interest of the subject required. The highly active properties of this element throw peculiar difficulties in the way of its examination, as it attacks with great violence, as far as is at present known, all substances with which we are acquainted, and thus deprives us of the means of insulating and preserving it. A strong argument in favour of the elementary nature of fluorine is derived from the fact that fluor spar is not decomposed by the *anhydrous* sulphuric acid. (§ 118.) There being no water to furnish oxygen to the calcium, or hydrogen to the fluorine, the hydro-fluoric acid cannot be produced.

If the supposition that fluoric acid is a compound of fluorine and hydrogen be correct, the analysis of its compounds proves that the two elements are combined in the proportion of

1 equivalent fluorine	-	18
1 ditto hydrogen	-	1
and that its number must be		19

Fluosilicic Acid. ?

(§ 350.) We have stated above, that fluoric acid acts upon glass in a very energetic manner; during this action it combines with the silex, of which it is composed, and assumes the gaseous form. This gas may easily be produced by pouring upon powdered fluor spar, mixed with half its weight of fine sand or glass, an equal weight of strong sulphuric acid. It may be collected over mercury, in glass jars, upon which it will no longer exercise any action. 100 cubic inches of it weigh 110.78 grains: it is colourless, and it affords, upon decomposition, 61 per cent. of silex. Its odour is penetrating, and its taste very

* So called from its assisting the fusion of earthy minerals in metallurgic operations.

sour. It extinguishes burning bodies, and produces white fumes when suffered to escape into the air.

Water absorbs about 263 times its volume of fluosilicic gas, and the solution may be kept in glass vessels. About 17 per cent. of the silica is precipitated during the absorption. The gas condenses twice its volume of ammonia, and forms with it a dry saline compound. It also combines with other bases. When pure potassium is burned in fluosilicic gas, it condenses it, and a brown substance is produced, which, after being boiled in water and dried, burns in oxygen gas. From the residue of the combustion, pure *silicon* may be obtained, by dissolving out some silex with which it is mixed by fluoric acid, and washing and drying the remainder upon a filter. This is the process to which we referred when treating of that element. (§ 176.)

Fluoboric Acid. ?

(§ 351.) If, instead of silex, fluor spar be mixed with half its weight of vitrified boracic acid (§ 184.), and 12 parts of strong sulphuric acid, and the mixture be gently heated in a glass retort; or if fluor spar, with boracic acid, be exposed to a strong heat in an iron tube, a gas may be collected in abundance over mercury which exhibits very peculiar properties. It is colourless, but possesses a very pungent odour, and instantly extinguishes flame. When it escapes into the air it occasions a dense white cloud, by combining with the aqueous vapour with which it is mixed. 100 cubic inches weigh 72 grains. It is rapidly absorbed by water, which takes up about 700 times its bulk; heat is given out, and the water increases in volume. The saturated solution is perfectly limpid, fumes when exposed to the air, and is very caustic. It acts with all the intensity of sulphuric acid upon organized substances, blackening and disintegrating them. It has no action upon glass. Potassium heated in fluoboric acid gas separates boron from it (§ 181.) in the form of an insoluble powder. It forms combinations with ammonia and other bases.

It is probable that both the fluosilicic and the fluoboric acids are binary compounds of fluorine; the former with silicon, the latter with boron; but the subject is as replete with difficulty as it is with interest; and although, in the present state of science, it affords one of the most promising fields of investigation to the accomplished chemist, it will not advance our design to enlarge upon it on the present occasion.

Chapter XII.

On the Compounds of Cyanogen.

(§ 352.) We have observed (§ 173.) that the *carburet of nitrogen*, to which the name of *cyanogen* has likewise been given, possesses the remarkable property of combining with elementary substances, in a manner perfectly analogous to that of the simple gaseous bodies: the mode of this combination and some of its most interesting results we shall proceed to examine.

When potassium is heated in cyanogen an energetic action ensues, the metal burns, and a saline body, the cyanuret of potassium, is generated. It also forms similar binary combinations with the other metals, the greater part of which, however, can only be obtained by the interchanges of a double decomposition. They are also perfectly neutral in their characters. (§ 26.)

Those compounds, however, which cyanogen forms with the non-metallic elements are of higher importance and interest, inasmuch as they are of an acid or electro-negative quality, and are capable of entering into combination with different salifiable bases.

Cyanogen and Hydrogen.

Hydrocyanic or Prussic Acid. 27.

(1 C. 26 + 1 H. 1.)

(§ 353.) If a narrow tube be filled with fragments of the saline body called cyanuret of mercury (§ 172.), and placed in a horizontal position, when a stream of sulphuretted hydrogen gas is passed through it, a double decomposition ensues: the sulphur of the gas combines with the metal, black sulphuret of mercury is formed, and the cyanogen which is liberated enters into a new combination with the hydrogen. The product may be expelled by a very gentle heat, and collected in a receiver kept cool by ice. A similar product may be obtained by moistening the cyanuret of mercury with muriatic acid, and distilling at a low temperature. The hydrocyanic acid is a colourless liquid, possessing a strong odour resembling that of peach-blossoms. In its pure state it is intensely poisonous, and a single drop of it placed upon the tongue of a dog causes almost

instant death. When greatly diluted with water it has the taste of bitter almonds, which, in fact, owe their flavour to a small portion of this acid. Water distilled from the leaves of the laurel also derives its poisonous quality from the presence of the same ingredient. The vapour of the pure acid takes fire on the approach of flame, and when mixed with oxygen gas detonates with the electric spark. It is extremely volatile, and boils at 79° Fah.; and at 0° it congeals. When a drop of it is suffered to fall upon a piece of glass it becomes solid; the cold produced by its rapid evaporation being sufficient to freeze what remains. Hydrocyanic acid reddens litmus paper feebly, and forms salts with the different salifiable bases. Owing to the tendency of its component elements to form other arrangements, it is very liable to spontaneous decomposition, and it is not easy to preserve it from change even out of the contact of the air in well-stopped bottles. The diluted acid is sometimes used in medicine. If a quantity of potassium sufficient to absorb 50 measures of cyanogen be heated in 100 measures of the vapour of hydrocyanic acid, an absorption of 50 measures takes place, cyanuret of potassium is generated, and 50 measures of pure hydrogen remain; proving that it is composed of equal volumes of its two ingredients.

Its composition is therefore

$$1 \text{ equivalent cyanogen } 26 = \begin{cases} 2 \text{ carbon } 12 \\ 1 \text{ nitrogen } 14 \end{cases}$$

1 equivalent hydrogen	1
and its combining proportion - -	27

The specific gravity of the vapour agrees with this determination, having been found to be the mean of its two ingredients.

Cyanogen and Oxygen.

Cyanous, Fulminic, and Cyanic Acids.?

(§ 354.) Much uncertainty still exists with regard to the compounds of cyanogen with oxygen, and they are rather objects of further investigation than of elementary instruction. A compound of a peculiar acid, into the composition of which oxygen and the elements of cyanogen enter, and potash, may be obtained by the following means: expose to a low red heat equal weights of a salt called the anhydrous *ferrocyanate of potash* and peroxide of manganese: pulverise the resulting mass and boil it with pure alcohol. On cooling the solution, a salt will be obtained in small crystalline plates. When a solution of this salt in water is merely heated, its acid is decomposed, and carbonic acid and ammonia are produced, and with greater certainty if a weak acid be added to the solution to assist in disengaging it from the potash. The result of an analysis founded on this property is, that it is composed of

1 equivalent cyanogen -	26
1 ditto oxygen -	8
	34

According to this analysis, the most appropriate name for this acid would be *cyanous acid.* It may be transferred from the potash by double decomposition to other bases, but, owing to the easy disunion of its elements, it has never been obtained in an insulated state.

(§ 355.) The elements of the same acid united (probably) in the same proportions, but further necessarily combined with some metallic oxide, (as that of silver or mercury, and the nature of which appears to be in some degree indifferent,) constitute another acid or class of acids, to which the name of *fulminic* has been given. This acid, like the preceding, has never been obtained in a separate state; but united, besides the metallic oxide which constitutes one of its ingredients, with a further proportion of the same oxide, or some other, as a base. It may also be transferred to different bases by double decomposition. All the fulminates detonate violently by heat or percussion, and some of them with the slightest friction. Their properties will be further described amongst the saline compounds.

(§ 356.) Another acid of this class has lately been discovered, in which cyanogen is combined with a second equivalent of oxygen, and upon which the appellation of *cyanic acid* may with propriety be conferred. It may be obtained by the action of hot water upon the *perchloride of cyanogen,* (a substance presently to be described): muriatic acid and cyanic acid result from double decomposition; the former of which may be expelled by heat, and the latter obtained in a separate form. It may even be procured, it is said, in the form of crystals by careful evaporation. It forms a distinct class of salts with the different salifiable bases, and its analysis has shown it to be composed of

1 equivalent of cyanogen		26
2 ditto	oxygen	16
making its number		42

Cyanogen and Chlorine.

Chlorocyanic Acid.—62.

(1 Ch. 36 + 1 Cy. 26.)

(§ 357.) If cyanuret of Mercury (§ 172.) be mixed with just sufficient water to reduce it to a semi-fluid state, and exposed to the action of gaseous chlorine, in the course of a few hours the colour of the chlorine will disappear, and a gas will be found in its place which is not absorbable by mercury, but instantly taken up by water. This is a true *cyanuret of chlorine* or the *chlorocyanic acid.* One portion of the chlorine, in this process, expels the cyanogen from the mercury, and forms bichloride of mercury, while another portion combines with the cyanogen, and forms the new compound. It possesses the remarkable property of crystallizing by a temperature of 0° Fah. (which may at any time be produced by mixing together pounded ice and common salt,) and may thus be separated from portions of other gases with which it would otherwise be liable to be contaminated. It becomes liquid about 8° or 10° Fah., and at 68° its pressure is equal to four atmospheres.

It constitutes an active poison, and is very caustic. It possesses a peculiar irritating odour; reddens blue vegetable colours, and does not explode when its vapour is mixed either with oxygen or hydrogen.

The constitution of chlorocyanic acid is probably

1 equivalent chlorine		36
1 ditto	cyanogen	26
		62

Perchloride of Cyanogen.—98.

(2 Ch. 72 + 1 Cy. 26.)

(§ 358.) By pouring about 15.5 grains of pure *hydrocyanic acid* (§ 353.) into a bottle containing about 61 cubic inches of dry chlorine, closing the bottle with a stopper, and exposing it to the direct rays of the sun, the hydrocyanic acid is volatilized, and after a few hours a colourless liquid may be seen on the inner surface, which gradually thickens, and finally sets into a white substance, mixed with shining crystals. This is the *perchloride of cyanogen.* When dry and pure it is brilliantly white, and may be obtained in needles. Its vapour affects the eyes, and, after keeping, exhales an odour of muriatic acid. It fuses at 140° Fah., and boils at 190°. It is extremely poisonous; and is sparingly soluble in cold water, and decomposed by hot, as we have already explained. (§ 356.)

Its composition has been ascertained to be

1 equivalent cyanogen		26
2 ditto	chlorine	72
		98

Cyanogen with Iodine and Bromine.

(§ 359.) Cyanogen forms binary compounds with iodine and bromine, analogous to the chlorocyanic acid, and whose properties resemble each other closely; it does not, however, consist with our purpose to enter upon their particular examination.

Cyanogen and Sulphur.

Sulphocyanic Acid.

(§ 360.) A compound of cyanogen with sulphur may be obtained by the following means:—Mix together equal weights of *ferrocyanate of potash,* (a salt which is more commonly known by the name of *prussiate of potash,*) and flowers of sulphur. Melt the mixture in a flask, by a gentle heat, and keep it melted for several hours. When cold, reduce the mass to powder, and dissolve out every thing soluble by digestion with water. Filter the solution, and drop into it a solution of potash, as long as any precipitate occurs. The liquid thus obtained is then to be distilled with sulphuric acid. An acid liquor will collect in the receiver, which is the sulphocyanic acid. It is transparent and nearly colourless, possessing only a slightly pink hue. Its smell is pungent, and resembles that of acetic acid (strong vinegar). It may be obtained in crystals, at a temperature of about 55° Fah., and boils at 217°. When thrown into a red-hot platinum crucible, sulphur is disengaged, which burns with a blue flame. If brought into contact with ignited iron-turnings, sulphuret of iron is formed, and hydrocyanic acid and sulphuretted hydrogen are disengaged. It is probable, from its most careful analysis, that it is a *triple* compound of cyanogen sulphur and hydrogen, or

1 equivalent of	cyanogen	-	26
2 ditto	sulphur	-	32
1 ditto	hydrogen	-	1
and that its number is		- -	59

The necessary existence, however, of the hydrogen in this substance is at present disputed.

It reddens litmus paper, and is capable of uniting with the different salifiable bases.

Cyanogen and Iron.

Ferrocyanic Acid.

(§ 361.) By adding the pigment called *Prussian blue* to a solution of barytes in water, till it ceases to be discoloured, and carefully evaporating the solution, crystals of a saline body may be obtained, which is called the *ferrocyanate of barytes.* If to a solution of this salt in water, sulphuric acid be carefully added till it ceases to form any precipitate, the liquid carefully decanted will consist of ferrocyanic acid, in which cyanogen is united with iron, and most probably with hydrogen, into an electro-negative compound. It has a pale yellow tint, possesses no smell, and permanently reddens litmus paper. It is decomposed by a gentle heat, or by exposure to a strong light, with the evolution of hydrocyanic acid; it cannot therefore be concentrated by evaporation or distillation in the common way. The same acid may however be obtained in crystals by the following process:—Dissolve crystals of tartaric acid in alcohol, and make a solution of ferrocyanate of potash in as little warm water as possible, in the proportion of 50 grains of the salt to 58 of the acid—mix the two liquids. An insoluble precipitate will be formed, and ferrocyanic acid will remain in solution in such a concentrated state, as to furnish yellow cubic crystals by spontaneous evaporation.

That the iron in this singular compound is a constituent element of the acid, and does not act the part of a base, is proved by the decomposition of one of its salts, the ferrocyanate of soda, by the electric pile. In this case, the iron passes with the other elements of the acid to the positive pole, whereas, if it existed as a base, it would be determined to the negative pole with the soda. In confirmation of this fact it may also be stated, that in the saline bodies formed by this acid with the different salifiable bases, the most delicate tests fail to detect the presence of the metal, as it can no more be affected by them than the sulphur can be indicated by its proper tests when existing in the different sulphates.

From the best analysis it is probable that the ferrocyanic acid is composed as follows:—

2 equivalents hydrocyanic acid	54 =	2 equivalents cyanogen	52
		2 equivalents hydrogen	2
1 equivalent cyanuret of iron	54 =	1 equivalent cyanogen	26
		1 equivalent iron . .	28
	108		108

The subject, however, is still one of controversy, into which we do not deem it expedient to enter at present.

Chapter XIII.

On the Hydroacids and their Compounds: with General Remarks on Salts.

(§ 362.) It now remains for us, in pursuance of our plan, to examine the results of chemical affinity between the compound electro-negative and electro-positive bodies which we have found to result from the combination of the non-metallic and metallic elements in very simple numbers and proportions; and to describe the more interesting of that numberless class of bodies formed by the union of acids and bases to which the name of salts has been given (§ 186). But before we proceed with this branch of our subject, we deem it expedient to make a few remarks upon a common property of one class of the foregoing acid compounds which may be distinguished from the general group—we allude to those, into the constitution of which hydrogen enters as the acidifying principle, and which may be designated as a class, by the name of *Hydroacids**. The following table will recal both their names and composition.

* See the note page 5

TABLE V.

HYDROACIDS.

	Equivalent.	Equivalent.		Equivalent.
Muriatic, or hydrochloric acid	37	1 Chlorine	+	1 Hydrogen.
Hydrobromic acid	76	1 Bromine	+	1 Hydrogen.
Hydriodic acid	125	1 Iodine	+	1 Hydrogen.
Hydrofluoric acid	19	1 Fluorine	+	1 Hydrogen.
Sulphuretted hydrogen	17	1 Sulphur	+	1 Hydrogen.
Bisulphuretted hydrogen	33	2 Sulphur	+	1 Hydrogen.
Hydrocyanic acid	27	1 Cyanogen	+	1 Hydrogen.
Sulphocyanic acid	59	1 Cyanogen	+	2 Sulphur + 1 Hydrogen?
Ferrocyanic acid	108	3 Cyanogen	+	1 Iron + 2 Hydrogen?

It will be observed, that the *radicles* of these acids (a term equivalent to *Base*, but which is only applied to the acids: chlorine being the simple radicle of the muriatic acid, and cyanogen and iron the compound radicle of the ferrocyanic acid) are united with one equivalent of hydrogen, except in the last instance, which probably contains two equivalents. Now we have seen that three of these bodies, muriatic acid, hydriodic acid, and sulphuretted hydrogen unite with ammonia, and form distinct salts (§§ 189. 190. 193.) and all the others are capable of the same union, and form analogous saline compounds with the volatile alkali; but, when brought to act upon any of the bases which contain oxygen, a different series of phenomena takes place: they generally combine in exactly such proportions, as that the hydrogen which they contain may be sufficient to form water with the oxygen of the oxide. Thus, one equivalent of the protoxide of mercury will be taken up by one equivalent of muriatic acid; but one equivalent of the peroxide requires two equivalents of the same acid for its solution. Experiment proves that, in such cases, water actually is produced, and the metal forms a binary combination with the radicle. Thus, when we oblige dry muriatic acid to act upon potash or barytes, water is produced, and the resulting compound is precisely the same as when we directly combine potassium or barium with chlorine. Again, we have seen that, by burning sodium in chlorine (§ 321.), we obtain the well-known substance, common salt, which is a *chloride of sodium:* by neutralizing muriatic acid with soda, we obtain exactly the same product. While in solution, there is nothing to prevent our considering this as a true salt, or a *muriate of soda:* but when we oblige it to assume the solid form by the evaporation of its water, we know that it contains neither oxygen nor hydrogen, and that it is a chloride of sodium. The converse of this proposition is also true, that any chloride dissolved in water may be regarded as the solution of the corresponding muriate, and, in some instances, we have demonstrative evidence that muriatic acid and an oxide are formed by the action of water upon a chloride. Thus, when chloride of antimony (§ 262.) is thrown into water, muriatic acid is produced, and a hydrated protoxide of mercury precipitated; as muriatic and sulphurous acids are generated by acting upon the chloride of sulphur by the same fluid (§ 126.). Nothing, on the other hand, prevents our conceiving the proper solution of a chloride, or of an iodide, in water, or obliges us to consider its nature altered by such solution. There is, it is true, something perplexing in the endeavour to follow this subject to its furthest consequences, but, after all, the difficulty is theoretical only, and it is perfectly indifferent whether we consider such compounds as chlorides or muriates, bromides or hydrobromates, cyanurets or hydrocyanates, &c. of the metals and their respective oxides; it being understood that these are only different ways of expressing the same phenomena. The least ambiguous examples of muriates of oxidated bases would seem to be those in which the compound, in crystallizing from its solution, carries with it a definite proportion of water, as water of crystallization: thus, muriatic acid will dissolve both the oxides of barium or strontium, and will afford crystals which differ from the respective chlorides by the water which they contain: these may, perhaps, be most properly called muriates; but, at the same time, it must be confessed that there is no very good reason for affirming, that the chlorides may not afford crystalline combinations, as such, with water.

Without giving too much importance

to these distinctions, we shall employ this double nomenclature, appropriate to the class of hydroacids, indifferently, as circumstances or facilities of explanation may seem to require. The different properties of the compounds depend solely upon the presence of the *radicle*, and are not affected by the elements of the water, in whatever way we imagine them to be combined; and we shall proceed to describe such of them as have not previously been examined with the binary compounds under the heads of their respective acids, in the general arrangement which we shall adopt of the saline bodies.

(§ 363.) We have before alluded generally to the mutual neutralization of acids and alkalies (§ 24.), and have explained the nature of salts, and the principles of the nomenclature by which they are distinguished (§§ 186. 196. 198.). It will be expedient to extend our general remarks upon this class of compounds previously to entering upon their individual characters.

It is a common mode of expression to speak of the solution of a metal in an acid; but without explanation this may be liable to misconception. No metallic body, as such, can be dissolved by an *oxy*acid: the action of the solvent is, first, to convert the simple element to an oxide, either by the decomposition of part of the acid itself, or of the water with which it is combined, and the salifiable base, thus formed, is afterwards taken up. This is even true of the *hydro*acids, whichever of the preceding views we may take of their combination; if we suppose that their radicles combine directly with the metals, it is still necessary that oxygen should be present to abstract their hydrogen: but if we imagine them to combine as acids, they can only unite with oxides. In some instances, indeed, the hydrogen of the acid itself is thrown off, but then the product is an undoubted binary compound, as *chloride*, *iodide*, &c. (§ 111.)

(§ 364.) In treating of the salts, it will facilitate our description to distinguish their physical from their chemical properties; by the former we understand the form, the colour, the taste, the smell, the density, fusibility, volatility, &c.; in the latter, we include the action of solvents, such as water, alcohol, and acids, and the effects of the various simple and compound bodies, as reagents. Some salts *decrepitate* when exposed to heat, that is to say, they fly in pieces with a crackling noise, as common salt when thrown into the fire. This is owing to particles of water mechanically entangled in the act of crystallization, and which suddenly assumes an elastic form. Those salts which contain water, chemically combined, seldom decrepitate.

Some retain their water of crystallization by such a feeble affinity, that atmospheric temperatures are sufficient to expel it in a dry atmosphere. Their crystals then fall into a powder, and are said to *effloresce*. Others have such a strong attraction for water, that they absorb the aqueous vapour from the air and melt into solution, or *deliquesce*.

Many *anhydrous* salts may be melted by the application of strong heat without undergoing any decomposition; and this phenomenon is designated by the term *igneous fusion*; and many which contain water of crystallization, when exposed to an increased temperature, dissolve in that water: and this is called *aqueous fusion*. A salt may first undergo aqueous fusion, have its water all expelled by heat, and then become fluid under the igneous fusion. The action of water upon salts is of the utmost importance, as it includes the phenomena of solution and crystallization. The solvent power of this fluid is in general in proportion to its temperature; but there are, nevertheless, some exceptions to this general rule, as common salt, which is equally soluble in hot and in cold water. Some salts are wholly insoluble in water, as the sulphate of barytes; while others deliquesce so rapidly as scarcely to be preserved separate from it, as the muriate of lime. Alcohol is a solvent which acts upon a limited number of salts; but scarcely can be said to dissolve any but the deliquescent. From this property, it is often used to separate salts which are mingled together; acids, also, sometimes act merely as solvents, without producing any change in the constitution of the salt: thus, phosphate of lime, which is insoluble in water in any appreciable quantity, is readily taken up by muriatic or sulphuric acid.

(§ 365.) In general, however, when, upon a salt or a compound of an acid with a base, we pour another acid, the base must be considered as divided between the two. For example, suppose we take chloride of sodium, which, when dissolved in water, as we have seen, may be considered as muriate of soda,

and pour upon it some sulphuric acid, we shall have two acids, the muriatic and the sulphuric, which will divide the soda between them. The acid which we add being in excess, part of the other acid will be set free; and if it should be of a volatile nature, will escape; but if fixed, it will remain, and while it remains, it is easy to conceive that it will exert its attraction upon the base. So that the latter may be considered as divided between the two acids; each of the acids opposing the action of the other. Now, there are many acids which are not volatile, and there are some which, although volatile, may be considered as fixed at common temperatures, because they are always combined with water; and, whenever an acid is retained in a liquid so as not to escape into the atmosphere, it may be considered as fixed. In the example to which we have referred above, the muriatic acid which we have disengaged will fly off, because it is gaseous, unless we have previously dissolved the salt; but if we have taken this precaution, the muriatic acid gas will remain dissolved in the water, and should be considered as fixed. The sulphuric acid acts in the same manner in both cases; but in the latter, the decomposition will be less complete, because the two acids oppose each other: while in the former, the muriatic acid escaping, there is nothing to check the action of the sulphuric. Hence, we may conceive, that the affinity of the acids for the bases depends greatly upon their fixity, and that, under particular circumstances, a volatile acid may be considered fixed. In the experiment above, where the muriatic acid is retained by the water, if the solution be heated, the acid will be volatilized in conjunction with the water, and the sulphuric acid will regain the ascendancy and totally displace the muriatic. It is usual to explain this process by supposing that the muriatic acid has less affinity for the soda than the sulphuric, but it probably depends entirely upon the volatility of the former, at the temperature at which it is conducted.

Analogous phenomena attend the presence of different bases with an acid. If we take a salt in solution, and add another base, the acid will be divided between the two bases. Let us take chloride of barium for example: if we add to it caustic potash, the chlorine will be shared between the barium and the potassium: if one of these bases be less soluble than the other, a portion will be set at liberty and precipitated; but if, before making the experiment, the solution of the chloride be greatly diluted, there will be no precipitate, because the whole will remain in solution.

Both these phenomena are of the same nature; the least soluble base corresponds to the volatile acid, and the precipitate to the disengagement of the gas. In one and the other case, a sufficient quantity of water can retain both bodies. Hence we may conclude, that when we pour a base into the solution of a salt, it will be that base which has least affinity for water, which will be disengaged. Thus, we shall find, that the soluble salts of lime are precipitated by barytes and strontian, and these again by potash and soda. The two bases divide the acid between them, when no disengagement or precipitate takes place. Again, when we mix together two different salts in solution, if by a mutual exchange of their acids and bases a salt can be formed of less solubility than those originally selected, double decomposition will certainly take place, and the less soluble salt will be precipitated, unless there should be sufficient of the liquid present to take it up. Hence we infer, that insolubility may determine the mutual decomposition and precipitation of salts. When solutions of sulphate of soda and nitrate of lime are mixed together, we may conceive that either acid would combine indifferently with either base; but sulphate of lime is formed, because, although a small quantity may at first be taken up by the water, it is insoluble in any considerable proportion in that liquid. It is thus that many cases of double elective affinity (§ 26.) may be explained, and if we are well acquainted with the relative solubility of the different salts, or their relative attraction for water, we may always anticipate the decompositions which will follow upon mixing their solutions. These phenomena are in strict accordance with the general principles which we expounded when speaking of the modifications which chemical affinity undergoes from the influence of cohesion, elasticity, and solution (§§ 28. 29. 31.). We shall avail ourselves in the sequel of opportunities of exemplifying the subject in detail.

(§ 366.) The salts may, without a figure of speech, be said to be numberless; and, of course, vary greatly in importance, both with regard to their application, to the arts of life, and to the instruction which may be derived from their study

It is necessary for convenience, to divide them into groupes, and they may be arranged either in the order of the acids or in that of the bases. By the former method, all the salts which contain sulphuric acid would be classed together; by the latter, all those which contain potash, &c. We shall, for the present, adopt the first arrangement, and commence our examination with the general character of each groupe, and then proceed to the particulars of such individual salts as we may think it conducive to our purpose to describe.

Chapter XIV.

On the Nitrates and Hyponitrites.

(§ 367.) The combinations of the nitric acid (§ 71.) with different bases, constitute a class of salts most important to the arts. When exposed to heat they are all decomposed, and the products are very various according to the nature of the base. If the attraction of the acid for the latter is but slight, it is given off without decomposition; but when stronger it is decomposed, and deutoxide of nitrogen, nitrogen, and oxygen, are evolved, according to circumstances. The different simple combustibles act variously, but with great energy upon the nitrates. At common temperatures they produce no effect, but when heated together different acids and oxides are formed. The nitric acid easily gives up its oxygen, which unites with the body thus presented to it. If we select nitrate of potash as an example, we shall find that with carbon it forms carbonic acid, and carbonate of potash will be the result; with phosphorus, phosphate of potash will be produced; and with arsenic, arseniate of potash. When the fixed acids are poured upon the nitrates they are decomposed, and nitric acid given off, and it is thus that nitric acid is procured for commerce, by distilling nitrate of potash with sulphuric acid (§ 72.).

The alteration which muriatic acid undergoes when brought in contact with the nitrates affords one of their most distinctive characters. In seeking to determine the nature of an unknown salt, if we mix it with a little muriatic acid and chlorine is given off in abundance, we may conclude that it is a nitrate. The hydrogen of the muriatic acid combines with the oxygen of the nitric acid, and both chlorine and coloured vapours of nitrous acid are disengaged. All the nitrates are soluble in water.

Nitrate of Potash.—102.

(1 N. 54 + 1 P. 48.)

(§ 368.) Nitrate of potash or nitre may be directly formed by neutralizing nitric acid with potash. It is composed of one equivalent of each of its ingredients. It crystallizes, in general, in six-sided prisms with striated surfaces; 100 parts of water at 32° dissolve 13.2 parts of the salt, but at 212° will take up 246.15 parts. It undergoes igneous fusion and becomes as liquid as water at a low red heat; it is sometimes cast into moulds and called *sal prunella.* At a white heat it is decomposed, and its acid resolved into nitrogen and oxygen. It undergoes no alteration in the air, but attracts moisture in a saturated atmosphere. Its taste is saline and cooling. The action of carbon upon nitre is very energetic, as may be seen by throwing a little upon lighted coals. The spots upon which it falls become instantly white hot. When a combustible body is mixed with nitre and gradually thrown into a heated crucible the process is called *deflagration;* it is employed when it is wished to unite different substances with oxygen. Sulphur treated in this way affords various products according to the proportion with which it is mixed. Equal parts of the two give rise to the formation of sulphate of potash, and oxygen is given off; two parts of sulphur and one of nitre occasion the formation of sulphurous acid in abundance; two parts of phosphorus and one of nitre yield a product of both phosphoric and phosphorous acids. All the metals may be oxygenated in this way, except gold, silver, platinum, and those rare substances which are found associated with the latter.

A mixture of three parts of nitre, two of carbonate of potash, and one of sulphur in powder, forms the *fulminating powder* which explodes with a loud noise when laid upon a metal plate heated below redness.

A mixture of five parts of nitre, one part of sulphur, and one of charcoal, finely powdered and very accurately blended, compose *gunpowder.* Great attention is paid in the manufacture of this important article to the purity of the ingredients: they are mixed together with great caution and pounded with wooden pestles with a sufficient quantity of water to prevent explosions. The mixture is granulated by passing through sieves, and carefully dried.

Nitre is found ready formed in nature; and particularly in certain countries of the east in a kind of efflorescence upon the ground after the rains. It also forms upon old walls and buildings, and generally in places where saline bases, such as lime, potash, or soda abound, and come in contact with decayed animal substances. In France and Germany it is artificially produced by forming beds of such matters, but the consumption of this country is chiefly supplied from the East Indies.

Nitrate of Soda.—86. ?

(1 N. 54+1 S. 32.)

(§ 369.) WHEN nitric acid is saturated with soda, instead of potash, the product shoots into crystals of nearly a cubic form, instead of six-sided prisms. Their taste resembles that of nitre, but is more pungent.

The nitrate of soda is more soluble in cold water than the nitrate of potash, 100 parts of water at 32° taking up 73 parts; but boiling water does not dissolve more than 173 parts. The results of the decomposition of the two salts are nearly alike. The former is more deliquescent than the latter, and therefore not so well adapted to the manufacture of gunpowder, but it is sometimes used, as more economical, in the formation of fire-works. It is but little employed in the arts.

Nitrate of Ammonia.

(1 N. 54 + 1 A. 17 + 1 W. 9.)

(§ 370.) THE composition and chief properties of nitrate of ammonia have been described when treating of the ammoniacal salts (§§ 80. 188.). We shall only now allude to the great cold produced by the solution of its crystals in water. Water, at 55° Fah., upon being saturated with this salt, will have its temperature reduced to 9°, a reduction of 46 degrees. But what is most remarkable, if a solution at 9° be mixed with water at 55°, there will be a further production of 9° of cold, and the mean density of the two fluids will be greater after the mixture than before, affording an example of a reduction of temperature by condensation, which is an exception to the general law.

Nitrate of Barytes.—132. ?

(1 N. 54 + 1 B. 78.)

(§ 371.) THE nitrate of barytes may be prepared by dissolving the carbonate of barytes in nitric acid diluted with 8 or 10 parts of water. 100 parts of water, at 32°, will only dissolve 5 parts of this salt, but of boiling water 35 parts. It is perfectly insoluble in alcohol and nitric acid: if, therefore, we pour concentrated nitric acid upon carbonate of barytes, it will not be taken up, as the nitrate first formed cannot be dissolved. If strong nitric acid be poured into a solution of the salt in water, it will be precipitated. Nitrate of barytes decrepitates by heat, and is decomposed into nitrous acid and oxygen. When the nitrate is wholly decomposed the *peroxide* of barium is produced, which, however, is not quite so pure as when formed by passing oxygen over ignited barytes (§ 330.).

Nitrate of Lime.—82.

(1 N. 54 + 1 L. 28.)

(§ 372.) NITRATE of lime is composed of one equivalent of nitric acid and one of lime. It forms crystals resembling bundles of needles diverging from a common centre. It rapidly dissolves in water, and is deliquescent. Alcohol also takes it up in abundance, and it may thus be separated from nitre, with which it is generally found mixed as a native production. It is very readily decomposed by heat, and yields nitrous acid in great quantities. The crystals contain a considerable quantity of water of crystallization, the amount of which has not been ascertained. When nitrate of lime has been kept fused for about ten minutes in a crucible, and then poured into an iron vessel previously heated, the congregated mass broken in pieces and exposed in a well-stopped bottle to the light of the sun for a few hours, will emit in the dark a beautiful white light. This preparation has been called *Baldwin's phosphorus.*

Nitrate of Copper.—188.

(2 N. 108 + 1 C. 80.)

(§ 373.) COPPER readily dissolves in nitric acid diluted with two or three parts of water to temper its action, which otherwise would be violent and dangerous. The metal becomes oxidated at the expense of a portion of the acid, deutoxide of nitrogen is given off in abundance, and the peroxide is dissolved by the remainder (§ 363.). Two equivalents of the acid thus combine with one of the oxide, and a large proportion of water, amounting to 14 equivalents. It ought strictly to be called the binitrate of copper. It forms crystals of a splendid blue colour, but the anhydrous salt is white. When

these crystals are coarsely pounded, sprinkled with a little water, and quickly rolled up in tin-foil, there is much heat produced, nitrous gas is rapidly evolved, and the metal generally takes fire. The salt is caustic, and corrodes the skin; its taste insupportably styptic. It is very soluble in water, and is even taken up by alcohol. By adding a small portion of potash or ammonia to its solution, or by greatly heating the dry salt, a *subnitrate* of copper is formed in which the acid exists in much smaller proportion to the acid. By heating the nitrate to redness, pure peroxide of copper may be obtained.

Nitrate of Lead.—166.

(1 N. 54 + 1 L. 112.)

(§ 374.) Nitric acid a little diluted dissolves lead with the extrication of deutoxide of nitrogen, or the same salt may be formed by digesting litharge (§ 232.) in the diluted acid. It crystallizes in white, opaque octohedrons which contain no water of crystallization. Their taste is sweet, like that of all the salts of lead. They are composed of one equivalent of both acid and base. The nitrate of lead is not very soluble, as 100 parts of cold water will only take up about 13 parts of the salt. When exposed to heat it decrepitates, then melts and gives off nitrous acid and oxygen. When distilled from a glass retort, the product condensed in a receiver, kept cool for the purpose, is a yellow liquid, which is said to be pure anhydrous *nitrous* acid (§ 69.).

A solution of nitrate of lead may be partially decomposed by ammonia, so as to form several *subnitrates*. On adding a very small quantity of the alkali a subnitrate is formed, composed of 1 equivalent of acid, and 2 of the base; a little more produces a compound of 1 equivalent of acid and 3 of base, and an excess of ammonia precipitates a salt composed of 1 of acid and 6 of base.

Protonitrate of Mercury.—262.

(1 N. 54 + 1 M. 208.)

(§ 375.) It will be recollected that mercury forms two oxides, which constitute salifiable bases (§ 203.): the nitric acid is capable of combining with both.

(§ 376.) The chemical nomenclature distinguishes such salts by transferring to the acid the Greek numeral, or preposition, which is used to designate the oxide (§ 55.). Thus the salt which the nitric acid forms with the *prot*-oxide of mercury, is called the *proto*-nitrate of mercury; while that with the *per*-oxide is termed the *per*-nitrate (§ 376.). The protonitrate of mercury may be formed by digesting mercury, at a low temperature, in nitric acid, diluted with three or four parts of water, until the acid is saturated; and then, allowing the solution to evaporate spontaneously, a small quantity of deutoxide of nitrogen is slowly given off during the process. A little of the metal should be left in the liquid to prevent the formation of a proportion of the pernitrate. The protonitrate may also be procured by boiling a solution of the pernitrate with an additional quantity of mercury. The newly added metal will become oxidated, at the expense of that already dissolved, and will be taken up by the acid. This salt may be wholly dissolved by water, slightly acidulated with nitric acid, but pure water has the property of precipitating from this and other mercurial salts, sub-salts of various composition.

The crystals of protonitrate of mercury contain water, probably to the amount of two equivalents.

Pernitrate of Mercury.—486.

(1 N. 54 + 2 M. 432.)

(§ 377.) When mercury is heated in an excess of strong nitric acid, it is dissolved with a brisk effervescence of deutoxide of nitrogen, and transparent prismatic crystals are deposited as the solution cools. This salt is composed of one equivalent of acid, and two of the base. If the solution be poured into cold water, a white precipitate is formed; or, if into boiling water, an orange-coloured one, consisting of nitric acid, with a great excess of oxide, and forming an insoluble *sub-pernitrate.*

We have stated (§ 203.) that the *pernitrate* of mercury may be decomposed by heat, and that the peroxide will remain. It is more correct to say, that the oxide so obtained still contains a small proportion of acid, and is therefore not so pure as when formed by heating the metal with access of air.

Nitrate of Silver.—172.

(1 N. 54 + 1 S. 118.)

(§ 378.) The nitric acid readily acts upon silver, and dissolves it with a copious disengagement of the deutoxide of nitrogen. When the metal is pure, the solution is colourless, contains a

slight excess of acid, and forms, by spontaneous evaporation, large regular crystals of the form of flat rhombs. This salt is composed of one equivalent of acid and one of base, and contains no water of crystallization. Water will dissolve of it about its own weight, at the ordinary temperature of the air, and alcohol about a quarter of its weight. The crystals of nitrate of silver fuse at a temperature under a moderate heat, and being poured into heated moulds, form the *lunar caustic* so much used in surgery.

A solution of this salt stains animal or vegetable substances of a deep black colour, after exposure to light. This seems to arise from a reduction of the oxide to the metallic state; for ivory, which has been so stained, will, when burnished, exhibit a bright metallic surface, resembling that of pure silver. This property is turned to account for marking linen, &c., in a permanent manner. For this purpose the cloth is moistened with a liquid made by dissolving two ounces of subcarbonate of soda and two drachms of gum-arabic in four ounces of water, and the solution of the salt itself thickened with a little gum, and coloured with Indian ink. The nitrate of silver is easily decomposed by a multitude of bodies. If it be mixed with a little carbon, and exposed to the temperature of boiling water, deutoxide of nitrogen and carbonic acid are evolved, and the silver is obtained in crystals. When mixed with phosphorus, and smartly struck with a hammer, the decomposition takes place with detonation; and if a stick of phosphorus be left immersed in its solution, it will become beautifully silvered. Most of the metals decompose it, and take its place with the acid. If a little mercury be poured into a bottle filled with a solution of the salt, after a little while the silver will be precipitated, of a beautiful form, resembling the branches of a tree, which has been called the *Tree of Diana.*

When the solution is contaminated (as often occurs) with copper, it may be purified from the latter metal by precipitating a portion of it with excess of potash. The precipitate will consist of a mixture of the oxides of silver and copper. This, when well washed, may be thrown into the remainder of the solution; and the oxide of silver having a greater affinity for the acid than the oxide of copper, the former will displace the latter, which will be precipitated.

The Hyponitrites.

(§ 379.) It will be remembered that there are two acids formed by nitrogen, of minor degrees of oxygenation than the nitric: namely, the nitrous and the hyponitrous (§§ 68. 69.), but the latter only affords salts with the different bases; as, when the former is made to act upon them, protoxide of nitrogen is disengaged and a hyponitrite formed.

The hyponitrites may be distinguished as a class by the red vapours which they emit when acted upon by other acids, such as weak sulphuric or nitric, or even acetic acids. The hyponitrous acid is thus decomposed into nitrous acid and nitrogen. Muriatic acid is not decomposed by them, nor chlorine evolved, as by the nitrates (§ 367.). When exposed, with different combustibles, to the action of heat, they are decomposed, in an analogous manner to the nitrates, but with much less energy. When their solutions, diluted with water, are boiled, they are decomposed, subnitrates are formed, and nitrogen disengaged.

Hyponitrites of Lead.

(§ 380). If we take 100 parts of nitrate of lead in crystals and 78 parts of lead in a state of fine division, and heat the mixture so as to make it boil, we shall obtain a salt, which, on cooling, will crystallize in beautiful gold-coloured needles. It may be considered as a subhyponitrite of lead, being composed of two equivalents of oxide of lead, and one of hyponitrous acid. It is but slightly soluble in water, and acts upon vegetable colours as an alkali.

If carbonic acid be passed into its solution, half the lead will be precipitated as a carbonate of lead, and a neutral hyponitrite of lead (that is to say, a salt composed of one equivalent of each of its ingredients) will be left in solution. A small quantity of sulphuric acid will also precipitate half the lead.

By adding a larger quantity of lead to the nitrate of lead, a yellow liquid will be obtained, which, upon evaporation, will yield octohedral crystals, resembling that of the nitrate itself, except in being yellow. This is another subhyponitrite, consisting of 3 equivalents of base: and lastly, by boiling together 2 parts of nitrate, 3 of lead, and 100 of water, until the whole is taken up, a brick-red salt will be obtained, composed of 4 equivalents of base. This salt contains

a proportion of water, but is less soluble than the others.

Hyponitrites of Copper, &c.

(§ 381.) THE hyponitrite of copper may be formed, by carefully pouring into a solution of sulphate of copper some hyponitrite of lead. A double exchange will take place, sulphate of lead will be precipitated, and hyponitrite of copper remain in solution.

Hyponitrite of iron and other hyponitrites may be formed by similar operations: but they have been little studied, and have not been applied to any practical purpose.

A hyponitrite of potash is probably formed, when nitrate of potash has been exposed to a moderate red heat, for if acetic acid be found upon the residue, it emits red fumes, whereas, before the application of the heat, the salt is not at all affected.

CHAPTER XV.

On the Chlorates, Perchlorates, and Combinations of Chlorine with Oxides.

(§ 382.) THE chlorates resemble the nitrates very much in general characters, and they are easily characterized as a class. The chloric acid contains the same number of equivalents of oxygen as the nitric (§ 92.), but still more loosely combined; so that its salts are decomposed with extreme facility, either by mere heat or by combustible bodies. They give off pure oxygen when exposed to a high temperature, and deflagrate readily when thrown upon ignited coals. When treated with sulphur, they form large quantities of sulphurous and sulphuric acids, and when treated with muriatic acid they yield chlorine and its protoxide. The sulphuric acid disengages from them peroxide of chlorine (§ 98.). With sulphur and phosphorus they detonate violently by percussion. They are never found as natural productions.

Chlorate of Potash.—124.
(1 C. 76 + 1 P. 48.)

(§ 383.) THE chlorate of potash may be formed by the direct combination of the acid and the base, or by passing chlorine into a concentrated solution of pure potash, until the latter is completely neutralized. The solution obtained by the last process, after being boiled for a few minutes, will contain both muriate and chlorate of potash. If gently evaporated, till a pellicle forms upon its surface, and suffered to cool, the chlorate will crystallize, and the muriate remain in solution. The chlorate of potash is perfectly anhydrous, and composed of one equivalent of acid and one of base. It is obtained crystallized in small scales, whose regular form is rhomboidal. Its taste much resembles that of nitre. It is but little soluble in cold water, but much more so in hot. It may be fused by a strong heat without decomposition; but upon increasing the temperature still further, it gives off 6 equivalents of oxygen, and chloride of potassium remains (§ 36.). It explodes violently by percussion, or trituration in a mortar, when mixed with sulphur or carbon; with phosphorus the experiment is dangerous, from the violence of the effects.

When thrown into concentrated sulphuric acid, enough heat is disengaged to inflame combustible bodies—such as sulphur and resins. It is to this property that the *instantaneous-light matches* owe their efficacy: three parts of chlorate of potash are mixed with one part of sulphur or sugar, and made into a paste with a little thick gum-water. The matches are dipped into the mixture, and when touched with sulphuric acid they instantly burst into flame.

Attempts have been made upon a large scale to manufacture gunpowder with this salt, instead of nitre; but so many serious accidents occurred from spontaneous explosions, that the attempt has been abandoned. Mixtures of it with different combustibles have been also applied for percussion priming to guns, but it was found seriously to act upon the barrels, and it has been abandoned for the fulminate of mercury, which has no corrosive property.

Chlorate of Soda.—108.
(1 C. 76 + 1 S. 32.)

(§ 384.) THE chlorate of soda is best prepared by the direct combination of the acid and the base: it may also be procured by the same process as the chlorate of potash, substituting soda for potash; but it is much more soluble than that salt in cold water, and therefore not so easily separable from the chloride of sodium with which it is mixed. It also assumes the cubic form in crystallizing; and is scarcely to be distinguished by the taste from the chloride. Its properties agree with those of the chlorate of potash.

(§ 385.) It may be well to mention

here, that when experiments are to be made upon the decomposition of substances which explode by heat, it is best to mix them with a large proportion of some inert substance in powder, such as sand, sulphate of potash, &c. Thus mechanically diluted, as it were, they only gradually receive the impression of the heat, in very small portions at a time; and, by adopting this precaution, the most explosive powders may be safely analyzed, and their gaseous products accurately collected.

Chlorate of Barytes.—154.

(1 C. 76 + 1 B. 78.)

(§ 386.) We shall describe one more of the chlorates, on account of the interest which attaches to it, from being the source whence the chloric acid is obtained (§ 92.). The fluosilicic acid (§ 350.) has the property of forming a salt with potash, which is insoluble at the ordinary temperature of the air. By mixing this acid in excess with a solution of chlorate of potash, an insoluble precipitate is formed with the alkaline base, which, at first, is of a gelatinous form, and scarcely visible, but afterwards becomes very dense: this must be separated by the filter. A solution of barytes in water, also in excess, is mixed with the clear liquid; and a current of carbonic acid is passed through it, which precipitates the excess of barytes in an insoluble form. It crystallizes in four-sided prisms; and 100 parts of water, at ordinary temperatures, will dissolve about 12 parts.

Perchlorates.

(§ 387.) This class of salts, and the acid of which they are composed (§ 94.), are but little known. They act with great violence upon ignited coal, on account of the great excess of oxygen which enters into their composition, and of which they possess two equivalents more than the chlorates. They are readily decomposed by heat and by all combustible bodies. The acid enters into combination with all the bases, and the products are perfectly neutral, (*i. e.* possess neither acid nor alkaline properties.)

Perchlorate of Potash.—148.?

(1 C. 100 + 1 P. 48.?)

(§ 388.) The perchlorate of potash may be obtained by gently heating, to the temperature of about 110° Fah., a mixture of one part of chlorate of potash with two of sulphuric acid. Peroxide of chlorine (§ 390.) is given off during the process, and a mixture of this salt with bisulphate of potash remains. The latter, being more soluble than the former, may be separated from it by washing, and by careful crystallization the perchlorate may be collected in small octohedral crystals.

It is quite insoluble in alcohol, and requires fifty-five times its weight of water at 60° for its solution: it, however, dissolves much more freely in water of 212°. It is from this salt that perchloric acid has been obtained, by distilling it with an equal weight of sulphuric acid at a temperature of 280° Fah. When exposed alone to a temperature of 412° Fah. it is converted into chloride of potassium and oxygen gas.

Combinations of Chlorine with the Oxides.

(§ 389.) Uncombined chlorine is also capable of uniting directly with potash, soda, lime, and, probably, other oxides. The compounds have but little stability, and must be carefully distinguished from those of the corresponding metals, or the chlorides of potassium, sodium, calcium, &c. The two first, which can only be obtained in the liquid form by passing a current of chlorine through solutions of the two alkalies, are speedily converted into mixtures of chlorates of potash or soda, and chlorides of potassium or sodium. They all possess powerful bleaching properties, and emit a faint smell of chlorine.

Chloride of Lime.

(§ 390.) The manufacture of chloride of lime (commonly called *bleaching powder*) is of great importance, and is carried on upon a very large scale. It is prepared by passing chlorine into chambers constructed for the purpose, in which strata of fresh slaked lime, in fine powder, is exposed to its action in trays. The gas is absorbed with rapidity, and much heat is evolved. It is necessary, indeed, to regulate this last circumstance by passing the current of gas very slowly into the apparatus, or by surrounding it with cold water; as a too high temperature determines the formation of a large proportion of chlorate of lime.

The chloride of lime is thus obtained in the form of a dry, white powder, which possesses a faint odour of chlorine, and a strong penetrating taste. When agitated with water, a portion is dissolved, which varies in different specimens. Its exact composition is a matter of contro-

versy; but it is probable that the dry powder consists of one equivalent of chlorine united with two of hydrate of lime, and that, when dissolved, one equivalent of the latter is precipitated; and that the chloride which remains in solution is composed of one equivalent of chlorine and one of the hydrate. When fresh prepared, with care, it does not contain any admixture of muriate of lime (*chloride of calcium*); but by long keeping, especially if moist, this salt is produced.

When exposed to heat, it is decomposed; a small quantity of chlorine and water are first given off, and, upon raising the temperature to 600°, the oxygen of the base is evolved, and chloride of calcium produced. The chlorine is also readily displaced by the different acids, even by the carbonic, whose affinities are probably the weakest of all.

It is very extensively used in bleaching, as it destroys colours nearly as efficaciously as chlorine itself. Its power for this purpose, and consequently its commercial value, may be estimated by its action upon a solution of indigo of known strength. When a solution of the chloride is exposed to the air, the carbonic acid gradually displaces the chlorine, which slowly escapes into the atmosphere, and carbonate of lime is produced. Advantage has been taken of this property for a most beneficial purpose, and one which cannot be too widely published, or too urgently enforced, by all those who may have it in their power to recommend it by precept or authority. Gaseous chlorine possesses the power of destroying the volatile principles given off by bodies in a state of putrefaction or infectious effluvia, and is often used with great advantage for the purposes of fumigation; but its smell is of such a suffocating nature, and so irritating to the lungs, that the greatest caution must be taken not to inhale it in any quantity. In the process, however, above described, it is so gradually evolved as not to occasion inconvenience; and it may be thus exposed, even in the chambers of the sick, without the slightest annoyance. Unpleasant exhalations are instantly neutralized by this salutary process, contagion checked, and a pleasant freshness communicated to the air, which does not merely cover disagreeable smells, like common fumigations, but effectually destroys them. The chloride is cheap and easily procured; and the quantity of a table-spoonful, stirred into as much water as may be contained in a soup-plate, and renewed every two or three days, is quite sufficient in all ordinary cases. During fevers of a decidedly infectious character, the solution should be sprinkled about the chamber, and the linen of the patient thrown into a pail of water in which double the above quantity of the salt has been mixed. There is reason to believe, from actual experiment, that the contagion of the plague itself may be stopped by these precautions. The full benefit of the discovery, however, can only be derived from the people acting for themselves in this matter, and not waiting for the recommendation of medical men, who, from their constant attendance upon disease, are possibly less alive to the dangers which surround them; and, except in very decided instances of infection, may sometimes be unfortunately afraid of the ridicule of giving way to unfounded alarm. The precaution is neither expensive, troublesome, nor unpleasant, and is perfectly within the reach of the poorest of the community. In no case can it be productive of any injurious effects; and he who is acquainted with the facts, is guilty of the grossest negligence who does not have recourse to such simple means of prevention, even in cases of the very slightest suspicion. We are well aware that we are exposing ourselves to some ridicule for so strongly enforcing such a subject in a scientific treatise; but when we consider that these pages are destined for thousands to whom other sources of such information are not accessible, we should feel ourselves guilty of the same kind of negligence which we strongly condemn in others, if we did not avail ourselves of the opportunity of widely extending the useful knowledge of the disinfecting power of the *bleaching powder*, or chloride of lime.

Chapter XVI.

On the Muriates and Chlorides.

(§ 391.) Referring to the general observations which we have just made, (§ 362.) upon the nature of the compounds of the *hydroacids*, we propose in this chapter to treat of the products of the action of the muriatic acid upon the different bases, and to describe their properties, whether as muriates or chlorides, with more particularity than it consisted with our purpose to do under the binary compounds. One of the distinctive characters of this class of salts, is their inalterability with the

simple combustibles, and particularly carbon. If, for instance, we mingle common salt (chloride of sodium) with charcoal, it will remain unchanged at any degree of heat to which we may expose it. They are all decomposed by the sulphuric acid, with the evolution of muriatic acid. If they be *muriates*, the sulphuric acid displaces the muriatic, and combines with the base: if *chlorides*, water is decomposed, the hydrogen passing to the chlorine, which escapes, as before, in the form of muriatic acid, and the oxygen to the metal, forming an oxide with which the sulphuric acid unites.

The mutual action of nitric acid and these salts is remarkable, and exemplifies the general law, which we have before explained (§ 365.), of the simultaneous action of two acids upon one base. If we pour nitric acid upon a muriate, a partial decomposition takes place, a certain quantity of a nitrate of the base is formed, and a certain quantity of muriatic acid disengaged; but the muriatic and nitric acids cannot exist together without mutual action; they form what the ancient chemists used to call *Aqua Regia*, because, so united, they have the power of dissolving gold, which they denominated the king of metals (§ 189.). The muriatic acid, disengaged by the nitric, and mixed with it, gives rise to a double decomposition: the hydrogen of the former unites to part of the oxygen of the latter, and water is formed, with chlorine and nitrous acid. It is the chlorine of this mixed fluid which dissolves the gold, and the nitrous acid is thrown off. In proportion as the chlorine is neutralized by the action of any metallic base, the decomposition of the two acids proceeds, and more is evolved.

If, on the other hand, muriatic acid in excess be made to act upon a nitrate, a chloride is formed; the oxygen of the base uniting with the hydrogen of the acid, and forming water: nitric acid is liberated, which re-acting upon the excess of muriatic acid in the manner just described, this mixture has also the property of acting upon gold.

The muriatic acid is most easily recognised by dropping into a solution of any of its salts a little solution of any salt of silver, as the nitrate. A white curdy precipitate is immediately formed, which is a chloride of silver (§ 210.). It is insoluble even in an excess of acid, but is taken up by ammonia. When exposed to light, it changes its colour to violet. The muriates and chlorides are all soluble in water, except the chloride of silver, the protochloride of mercury, and some subchlorides.

Chloride of Silver.—146.

(1 S. 110+1 C. 36.)

(§ 392.) The formation and composition of the chloride of silver have been already described (§ 210.). To the account there given of its properties, we have but few particulars to add. It is tasteless, on account of its perfect insolubility; which is so absolute, that a drop of nitrate of silver will occasion an obvious opacity in water which contains but $\frac{1}{300,000}$ part of muriatic acid. It is also insoluble in alcohol, and all the acids except concentrated muriatic acid, which takes up a small portion of it; but it is again precipitated by pouring water into the solution. It is, as we have before observed, abundantly dissolved by ammonia, but may be disengaged from it by neutralizing the alkali by an acid. Upon gently evaporating the ammoniacal solution, the chloride may be obtained in crystals. It is also taken up in small quantities by a concentrated solution of common salt and some other chlorides; and if a solution of muriate of soda be evaporated in a silver vessel, it will become alkaline, and a sensible quantity of silver will be dissolved. Chloride of silver may be decomposed by the contact of zinc or iron, with the intervention of a little muriatic acid; the zinc is dissolved, and gradually abstracts the chlorine from the silver, leaving it in the metallic state in the form of a porous mass. This decomposition may be rapidly effected, on a large scale, by heating the mixture in an iron vessel; the zinc abstracts the chlorine, and the silver may be obtained pure by mere washing. In no instance does the chloride of silver enter into combination with water, and there is, consequently, less room for distinction between the direct combination of the metal and chlorine, and the oxide and muriatic acid, than in many instances of this class of salts.

Chlorides of Gold.

(§ 393.) We have already referred to the uncertainty which exists with regard to the composition of the chlorides of gold: a few additional particulars may not be without interest. The saturated solution of the metal in nitro-muriatic acid yields, by careful evaporation, crys-

tals of a deep orange colour, which rapidly attract moisture from the air, and are readily decomposed by heat, the chlorine escaping, and the gold remaining in the form of a spongy mass. This salt, which is often lesignated as the muriate of gold, contains a considerable proportion of water of crystallization; but when strong sulphuric acid is poured into a saturated solution of it, *anhydrous chloride of gold* is precipitated. The solution of gold is so easily decomposed, that the action of light is sufficient to reduce the chloride; and, unless carefully excluded from its agency, the glass which contains it soon becomes lined with a brilliant coat of the revived metal. It is often used in the arts for obtaining a precipitation of gold for various ornamental purposes; and this kind of gilding is effected by the agency of a great variety of substances which have a strong attraction for oxygen, which abstract it from the water of the solution, and leave the hydrogen to combine with the chlorine, which then separates from the metal. A splendid purple colour is also obtained from it by precipitation with proto-chloride of tin, which is much used in enamel painting, and for tingeing glass of a fine red. It is known by the name of *purple of Cassius*. If *concentrated* solutions of the two chlorides be mingled together, in any proportions, metallic gold will be precipitated; but if both be diluted with water previously to their mixture, a purple powder will be thrown down, which consists of a mixture of peroxide of tin and metallic gold, whose proportions appear to vary according to circumstances.

(§ 394.) When solutions of the alkalies are added to the solution of gold, the whole of the metal is not thrown down: one portion is precipitated in the form of oxide, but another is retained in triple combination with the acid and alkali. Salts thus constituted of two bases are distinguished by the name of *double salts*. When potash is added to the solution of chloride of gold, a part of the metal precipitates, and a *double chloride of gold and potassium* is formed, which is very soluble, and not decomposed by any further addition of the alkali. Similar *double salts* may be formed by the action of soda, lime, and even magnesia; but they have been very little attended to. The *double chloride of gold and sodium* may also be obtained by dissolving 300 parts of gold in nitro-muriatic acid, and adding 19 parts of common salt (chloride of sodium.) Yellow prismatic crystals may be obtained by evaporating the solution.

When solution of gold, diluted with about 3 parts of water, is mixed with liquid ammonia, a brownish precipitate is formed, which, washed and carefully dried, at a temperature not exceeding 212°, is known by the name of *fulminating gold*. It explodes violently by friction, and by the electrical shock. It is supposed to be a compound of oxide of gold and ammonia, in the proportion of about 5 parts of the former to 1 of the latter. In its sudden decomposition the oxide of the gold unites with the hydrogen of the alkali, and forms water; the gold is reduced, and nitrogen is evolved.

Chlorides of Platinum.

(§ 395.) The direct combination which we formerly described (§ 220.) of platinum with chlorine, is most probably a *proto-chloride* of that metal. If the solution of pure platinum in nitro-muriatic acid be evaporated to dryness at a gentle heat, and the temperature not subsequently raised, a brown deliquescent mass will be obtained, which is very soluble both in water and alcohol. This is a *perchloride*, and is, probably, composed of

1 equivalent of platinum	.	96
2 ditto chlorine	.	72
		168

but it also contains combined water, and in this state is known by the name of *permuriate* of platinum. It is easily decomposed, with revival of the platinum, by a great many of the metals, and different combustible bodies. It is converted into the proto-chloride by a temperature not exceeding 430° F.; but, by a higher heat, all the chlorine is expelled, and the pure metal remains. Perchloride of platinum unites with the chlorides of the alkaline metals to form double salts analogous to the double chlorides of gold.

The *double chloride of platinum and potassium* is formed by mixing chloride of potassium with perchloride of platinum. It is very sparingly soluble in water, and quite insoluble in alcohol: it is of a yellow colour, and crystallizes in small octohedra. It consists of

1 equivalent perchloride of platinum	168
1 ditto chloride of potassium	84
	252

This salt is formed whenever the alcoholic solution of the perchloride is added to a concentrated solution of any salt whose base is potash, and thus the salts of potash may be distinguished from all others.

A similar *double chloride of platinum and sodium* may also be formed which is soluble both in water and alcohol.

A *double muriate of platinum and ammonia* is produced in abundance by adding a solution of muriate of ammonia to the perchloride of platinum. The precipitate is of a light yellow colour, and composed of

1 equivalent bichloride of platinum	168
1 ditto muriate of ammonia .	54
	222

When this ammonio-muriate is strongly heated, the ammonia and the chlorine are driven off, and pure metallic platinum remains in a peculiar spongy disintegrated state; from which the malleable platinum used in the arts is prepared by welding at a high heat with strong pressure.

Platinum, in the slightly-coherent state in which it is obtained by the decomposition of this double muriate, possesses the remarkable property of determining the union of hydrogen and some other inflammable gases with oxygen; and when a stream of the former is directed upon a small particle of the metal thus prepared, it speedily becomes white hot, from the great quantity of heat which is disengaged, and the gas is inflamed. The process cannot at present be said to be perfectly understood, but probably originates in a mechanical condensation of the gas in the pores of the spongy mass, analogous to that which we have described as taking place with fresh-prepared charcoal (§ 153.). Some other metals, in a state of fine division, possess the same property at higher temperatures and in a less degree.

Chlorides of Copper.

(§ 396.) We have seen (§§ 344, 345.) that the two chlorides of copper have a yellowish colour, which is of no great intensity; and that the protochloride is insoluble in water. Muriatic acid, when concentrated, acts upon metallic copper with difficulty at a boiling heat; but the peroxide is readily dissolved by the acid, and forms a green solution of different degrees of intensity, according to its concentration. By careful evaporation green prismatic crystals may be obtained, which are deliquescent and very soluble both in water and alcohol. The proportions of metal and chlorine are the same as in the perchloride; but, in addition, it contains a definite proportion of water of crystallization, and in this state is often called *permuriate of copper*. It parts with this water at a moderate temperature, and then in no respect differs from the perchloride.

When copper is merely wetted with muriatic acid or a solution of common salt, and exposed to the air, an oxide is formed united to a little chlorine. This sub-salt is also formed when a sufficient quantity of any alkali is poured into a solution of the permuriate to decompose it. It is of a blue colour, and used as a paint, which is unchanged by exposure to the air.

Chloride of Cobalt.

(§ 397.) A CHLORIDE of cobalt may be prepared by dissolving the metal in muriatic acid; during the solution hydrogen gas is evolved. When the solution has been evaporated to dryness, and the residue heated to redness, out of the contact of air, a deep blue salt is obtained of a lamellated or micaceous texture, which is the pure anhydrous chloride. It forms a pink solution in water, which, by careful evaporation, yields crystals, which contain a definite proportion of water, and are sometimes called the hydrated chloride, and sometimes the muriate of cobalt. The pink solution changes colour according to its degree of concentration, and when heated to the boiling point assumes an intense blue colour. If the metal, from which the chloride has been made, should not have been perfectly pure, but slightly contaminated with iron, nickel, or arsenic, the colour produced is green. If the pale pink solution be employed to write upon paper, the characters, when dry, will be invisible; but if the paper be held before a fire, the writing will appear in bright blue or green. As the paper cools, the colour will again disappear in consequence of its absorbing moisture from the air; and the phenomena may be reproduced many times in

succession. When employed for this purpose it is called a *sympathetic ink.*

Muriates of Tin.

(§398.) By boiling one part of tin with two of muriatic acid, a solution may be obtained, which yields by concentration a crop of deliquescent crystals, which consist of proto-muriate, or hydrated-protochloride of tin (§ 287.). The solution has a great attraction for oxygen, which it quickly absorbs from the air and from several metallic solutions which it deoxidizes and revives. It is much used in the arts of dyeing and calico printing, to change colours and to fix them. With infusion of cochineal it produces a purple precipitate.

During the absorption of oxygen from the atmosphere, part of the tin is thrown down in the state of peroxide, and another part combines with a second equivalent of chlorine or muriatic acid, and *permuriate* or *perchloride* of tin (§ 288.) remains in solution: the same solution may at once be obtained by dissolving tin in nitro-muriatic acid, or a mixture of nitric acid and common salt, or muriate of ammonia. It is also much used by dyers, and produces a scarlet colour, with infusion of cochineal.

Chapter XVII.

On the Bromates and Hydro-bromates, or Bromides — and on the Iodates and Hydriodates, or Iodides.

(§ 399.) The combinations of the bromic and hydro-bromic acids with the different bases, or of bromine with the several metallic elements, have hitherto been too little studied to enable us accurately to characterize them as classes, and they are of too rare occurrence to render the omission of any consequence to the student. The bromates, however, are generally analogous to the chlorates (§ 382.): they deflagrate when thrown upon ignited charcoal, and give off pure oxygen when heated.

The hydro-bromates precipitate the solutions of silver like the muriates (§ 391.); the bromide of silver which is formed has the same curdy appearance as the chloride, and becomes black by exposure to light. It is also soluble in ammonia, and insoluble in boiling nitric acid. Boiling sulphuric acid, on the other hand, disengages vapours of bromine, by which it may be distinguished. We shall proceed to describe two or three of the salts as illustrations of the subject.

Bromate of Potash.

(§ 400.) When the ethereal solution of bromine (§ 100.) is shaken up with solution of potash, bromate of potash and bromide of potassium are both produced. The former separates in the form of a crystalline powder. It is soluble in water, and slightly so in alcohol, and it crystallizes in needles. It acts like nitre upon hot coals, and is converted into bromide of potassium by the disengagement of its oxygen. When mixed with sulphur it may be made to detonate by a blow. It is sparingly soluble in water, and its solution occasions a white precipitate in nitrate of silver, by which it may be distinguished from chlorate of potash, which it otherwise resembles.

Bromate of Baryta.

(§ 401.) If the solution of bromine in ether be agitated with the aqueous solution of baryta, two salts are also produced, viz. the bromate of baryta and the bromide of barium. The former may be obtained in needle crystals, and is the source from which the bromic acid is obtained, as before mentioned (§ 102.). It produces a vivid deflagration when thrown upon ignited charcoal.

Hydro-Bromate of Potash, or Bromide of Potassium.

(§ 402.) Bromine and potassium act intensely on each other, with evolution of light and heat: a white crystallized substance is the result. The same salt is obtained in combination with water, by agitating together, as above stated (§ 400.), solutions of bromine and potash, or by the direct saturation of hydro-bromic acid (§ 103.) with potash. It crystallizes in cubes, and is much more soluble than the bromate, a property which renders it easily separable from the latter.

Hydro-Bromate of Baryta, or Bromide of Barium.

(§ 403.) The hydro-bromate of baryta may be formed as above-mentioned (§ 401.), or by the direct combination of the acid and base. It is very soluble in water, and is also taken up by alcohol. By evaporation of the solution it may be obtained in opaque mammilated crystals.

Hydro-Bromate of Ammonia.

(§ 404.) Hydro-bromic acid gas unites with its own volume of ammoniacal gas, and forms a white volatile salt. It crys

tallizes in long prisms, and is soluble in water. By exposure to the air it becomes yellow, and slightly acid.

The Iodates.

(§ 405.) We have seen that the iodic acid is analogous in composition to the chloric acid (§ 108.): the general character of the iodates is also similar to that of the chlorates. They form deflagrating mixtures with inflammable bodies, and give out oxygen gas at a low red heat. A metallic iodide generally remains after this operation, but, in some cases, iodine itself is liberated. They are easily distinguished, as a class, by the disengagement of iodine when exposed to the action of deoxidizing substances, as the sulphurous, phosphorous, muriatic, and hydriodic acids. They are, in general, very sparingly soluble in water.

Iodate of Potash.—212.
(1 I. 164 + 1 P. 48.)

(§ 406.) The iodate of potash may be obtained by projecting iodine into a hot strong solution of pure potash till the alkali is neutralized. By evaporating the solution to dryness, a mixture of iodate and hydriodate of potash is obtained, from which the latter may be washed by strong alcohol, the former being perfectly insoluble in that fluid. It is a difficultly soluble salt, and gives out about 22 per cent. of oxygen at a red heat, and is thereby converted into iodide of potassium. All the insoluble iodates may be obtained from this salt by double decomposition; as, for instance, the iodate of baryta, by mixing the muriate of baryta with its solution.

None of them possess sufficient interest to require description.

The Hydriodates, or Iodides.

(§ 407.) In considering the combinations of the hydriodic acid with the different bases, we must recollect its close analogy to the muriatic acid (§ 111.), and the observations which have been made upon the combinations of the hydro-acids in general (§ 362.). Whenever sulphuric acid, nitric acid, or chlorine, are brought into contact with a hydriodic salt, either in the solid state or in solution, iodine is disengaged, and may be recognized by its colour. If the latter agent, however, should be in excess, the iodine will be dissolved, and the colour will disappear. The presence of iodine may also be recognized by the precipitate of iodide of silver, which is formed by the addition of a solution of silver to a solution of any of this class of salts. It is white, and insoluble in water or the acids. It is also insoluble in ammonia, by which it may be distinguished from the chloride and bromide of the same metal.

Iodine possesses likewise the property, which we have before noticed (§ 106.), of communicating a beautiful and peculiar blue colour to starch; so that, if a little of this vegetable substance be mixed with an iodide, and sulphuric or nitric acid be added, it is immediately characterized by this distinctive property.

Hydriodates of Iron and Zinc.

(§ 408.) The hydriodate of iron and the hydriodate of zinc may be formed by digesting thin fragments of the respective metals in water in which iodine is suspended. The combination takes place with great rapidity. They may each be obtained in crystals, by evaporation of their solution. The anhydrous iodides may also be procured by the action of iodine upon the metals, without the intervention of the water. The iodide of iron is a brown compound, fusible at a red heat, but, when combined with water, it is of a green colour.

Hydriodate of Potash.—173.
(1 $\dot{H}$. 125 + 1 P. 48.)

(§ 409.) The hydriodate of potash may be produced by the direct neutralization of the hydriodic acid, by the alkali, or by the double decomposition of either the hydriodate of iron or zinc, by carbonate of potash. It crystallizes in cubes, and is very soluble in water. The anhydrous salt, or iodide of potassium, may be formed by the direct action of iodine and the metal, which combine together with great energy. It is of a crystalline texture, white, and fusible at a red heat. The solution of this salt, as of all the hydriodates, is capable of dissolving a considerable quantity of iodine, whence it derives a purple colour. This salt, or the hydriodate of soda, constitutes the residue of the solution of *kelp*, which we have previously described (§ 105.) as the source from which iodine is derived. It also exists, in very minute proportions, in the waters of the sea. It has lately been applied, with some success, in medicine.

Iodide of Barium.

(§ 410.) By acting upon baryta with hydriodic acid, a solution may be obtained which crystallizes by evaporation. The salt is anhydrous, and, when its solution is exposed to the air, it is decomposed, and carbonate of baryta formed. When the iodide of barium, and the corresponding iodides of strontium and calcium are exposed to heat in contact with the air, iodine is given off, and baryta, strontia, or lime, remain; but the iodides of potassium and sodium are unchanged by heat. In the former case the metallic bases have a stronger affinity for oxygen than for iodine at a high temperature, but in the latter the order of the attraction is reversed.

Hydriodate of Ammonia.—142.

(1 H. 125 + 1 A. 17.)

(§ 411.) Equal volumes of hydriodic acid and ammoniacal gases combine together and form deliquescent cubic crystals, which are volatile in close vessels without decomposition. When exposed to the contact of air and moisture, they are speedily decomposed, with disengagement of iodine.

Chapter XVIII.

On the Sulphites and Sulphates—Hypo-Sulphites and Hypo-Sulphates—Hydro-Sulphurets or Sulphurets—and Sulphuretted-Hydro-Sulphurets.

(§ 412.) The salts which the sulphurous acid (§ 116.) forms with the different bases are easily distinguished as a class. Those which are soluble, as the sulphites of potash, soda, lithia, and ammonia (the rest being nearly insoluble), are characterized by a sulphurous taste. When the stronger acids, as the sulphuric, muriatic, phosphoric, &c. are poured upon any of them, the sulphurous acid is disengaged with effervescence, which may be easily recognized by its suffocating smell. By exposure to air they absorb oxygen, and are changed into sulphates. They are all decomposed by heat; part of their sulphur sublimes, and the remainder, uniting with the additional equivalent of oxygen, changes the salt into a sulphate: part of the base, however, is disengaged, as enough sulphuric acid cannot be formed to neutralize the whole. The soluble salts of baryta, strontia, and lime decompose the alkaline sulphites, because the sulphites of the same earths are insoluble (§ 365.)

Having enumerated these general properties of the class, the subject has too little interest to require that we should enter at any length into the description of the individual species: they have been applied to little use, and have been but slightly examined.

Sulphite of Lime.

(§ 413.) The sulphite of lime may be best procured by passing sulphurous acid gas through water in which powdered chalk is suspended as long as any effervescence is produced. If carried beyond this point, the excess of sulphurous acid would redissolve the product. It is thus obtained in the form of a white powder, which may be preserved in close bottles, as a convenient source of the sulphurous acid. It is used in wine countries for regulating the fermentation of the vats.

Sulphite of Potash.

(§ 414.) Sulphite of potash may be formed by passing sulphurous acid into a solution of the alkali or its carbonate. It must be subjected to evaporation out of the contact of the air, when white crystals will be produced in the form of plates. They are very soluble, and their taste is sulphurous. A bisulphite of potash is at the same time formed, which separates first from the solution.

The Sulphates.

(§ 414.) Of far higher importance are the salts formed by the sulphuric acid (§118.): many of them are found in nature in abundance, and many are largely employed in the arts. The sulphates afford neither effervescence nor disengagement of vapour by the affusion of any acid at ordinary temperatures; but the sulphuric acid may be displaced at a high heat by the boracic, phosphoric, and arsenic acids. When exposed alone to a high temperature, the sulphates are all decomposed, except those of potash, soda, lithia, baryta, strontia, lime, magnesia, and lead. All the others afford sulphurous acid and oxygen by the action of a red heat. Such as contain no water of crystallization give out, moreover, a portion of anhydrous sulphuric acid (§ 118.) as the sulphate of iron.

The whole class, not excepting those which resist decomposition at an elevated temperature, may be decomposed by carbon and a high heat. The acid and the oxide are both decomposed, and a sulphuret formed. A similar change is effected by hydrogen gas, at a red

heat. Water is formed, and not unfrequently some sulphuretted hydrogen.

The soluble sulphates may be recognized by the dense white precipitate which is formed upon pouring into them a solution of any salt of baryta. The sulphate of baryta thus produced is wholly insoluble in water, acids, or alkalies. By boiling the insoluble sulphates with three times their weight of carbonate of potash or soda, a double decomposition takes place, carbonate of baryta is formed, and a sulphate of the alkali; in which the acid may, of course, be detected by the same process.

Sulphate of Silver.—158.

(1 Sul. 40 + 1 Sil. 118.)

(§ 416.) Diluted sulphuric acid will not act upon silver; but when concentrated and boiling, it forms with it a white saline mass, easily fusible. It requires 90 parts of water at 60° for its solution; but it is more soluble in boiling water, from which it separates on cooling in small prismatic crystals. It is decomposed at a red heat, and metallic silver remains. The action of sulphuric acid is employed in a very large way for separating small portions of gold from silver. The gold is not touched by the acid, and is collected in the form of a black powder. The silver is afterwards recovered from the sulphate by the action of metallic copper which combines with the acid, and precipitates it in a pulverulent state.

Proto-sulphate of Mercury.—248.

(1 S. 40+1 M. 208.)

(§ 417.) There are two sulphates of mercury corresponding to the two oxides of that metal. If one part of mercury be gently heated with one and a half of sulphuric acid, sulphurous acid gas will be given off, and a white mass obtained, which, after being washed with water, will be the proto-sulphate of mercury. It is soluble with difficulty, and requires for that purpose 500 parts of cold and 300 of boiling water, and crystallizes in prisms. It is composed of

1 equiv. of protoxide mercury	208
1 ditto sulphuric acid . . .	40
	248

The alkalies give a black precipitate of the protoxide with the salt.

Per-sulphate of Mercury.—296.

(2 S. 80+1 M. 216.)

(§ 418.) If five parts of sulphuric acid be boiled to dryness with four of mercury, a white crystalline mass will be obtained, which is the per-sulphate of mercury. It is immediately decomposed by the agency of water into a soluble super-sulphate and an insoluble sub-sulphate of mercury, so that it cannot exist in solution. The sub-salt thus precipitated is of a yellow colour, and was formerly known in medicine by the name of *turpeth mineral.* The per-sulphate of mercury is composed of

1 equiv. of peroxide mercury	216
2 ditto sulphuric acid . .	80
	296

It is this salt which is used for the preparation of the bi-chloride of mercury by double decomposition with common salt or muriate of soda (§ 205.)

(§ 419.) Our principal reason for particularly describing this salt is to introduce the remark, that the quantity of acid which the oxides of the same metal require for saturation is generally in the same proportion as the quantity of oxygen contained in their oxides. Thus we see that the peroxide of mercury, which contains two equivalents of oxygen, takes double the quantity of sulphuric acid which the protoxide requires which only contains one equivalent. The observation, though not quite universal, may be useful. We have already seen one exemplification of it in the nitrate of copper (§ 373.), in which the *deutoxide* of that metal is combined with two proportions of the nitric acid, and more will be adduced as we proceed. An exception, however, has already occurred in the per-nitrate of mercury in which two equivalents of the peroxide are saturated by one equivalent of the acid.

Persulphate of Copper.—250.

(2 S. 80 + 1 C. 80 + 10 W. 90.)

(§ 420.) The persulphate of copper has long been known in commerce by the name of *blue vitriol.* It forms splendid crystals of a fine blue colour, which contain ten equivalents of water of crystallization: it however parts with this water by exposure to heat and becomes white. The colour may be restored by the addition of water. It is essentially composed of two equivalents of sulphuric acid and one of the peroxide of copper, and exemplifies the remark which we have just made (§ 419.). There is at present no known combination of the sulphuric acid with the protoxide of copper; for when this acid and base are digested together, metallic cop-

per and a solution of the peroxide are obtained. The persulphate may be produced by boiling copper filings in diluted sulphuric acid, when abundance of sulphurous acid is emitted: or the peroxide of copper may be quietly dissolved in the same acid. It is manufactured upon a large scale by exposing roasted sulphuret of copper to air and moisture, from which both the sulphur and metal abstract oxygen. This salt is used in medicine, and is the source from which many blue and green paints are prepared. When an alkali is cautiously added to a solution of the preceding salt in quantity not sufficient to neutralize the acid, a *sub-persulphate* is precipitated of a pale blue colour. It is composed of

2 equivalents of	peroxide of copper	160
, ditto	sulphuric acid .	40
		200

The same compound is also formed by the addition of carbonate of lime, when carbonic acid is given off with effervescence.

An excess of alkali throws down from the solution the peroxide of copper in combination with water.

Proto-sulphate of Iron.—76.
(1 S. 40 + 1 I. 36.)

(§ 421.) This salt may be formed by acting upon metallic iron by dilute sulphuric acid. Water is decomposed during the process, the oxygen of which passes to the metal to constitute the salifiable base, and the hydrogen is given off with effervescence (§ 40.). It is manufactured on the large scale by exposing the roasted bisulphuret of iron, in small pieces, to the combined agency of air and moisture.

It forms light green prismatic crystals, which contain six equivalents of water. They are soluble in twice their weight of cold water, and have a styptic, ferruginous taste. They are neither soluble in alcohol nor in sulphuric acid; and, if the latter be poured into a strong solution of the salt, it will be precipitated, in an anhydrous state, in the form of a white powder.

When exposed to heat, the proto-sulphate of iron first loses its water of crystallization, and becomes of a dirty-white colour; and, when the heat is continued to redness, it is decomposed. The protoxide is converted into peroxide, and remains in the form of a red powder, which is known in the arts by the name of *colcothar*. It is used as a paint, and for polishing mirrors. This salt, either in crystals or solution, when exposed to the air, becomes stained with an ochreous colour from the absorption of oxygen. A *sub-persulphate* is thus formed which is insoluble.

Per-sulphate of Iron.—100.
($1\frac{1}{2}$ S. 60 + 1 I. 40.)

(§ 422.) The proto-sulphate of iron is changed into per-sulphate by the action of chlorine or nitric acid. The persulphate may also be formed directly by the action of sulphuric acid upon the red oxide of iron slightly moistened. If the acid be concentrated, the product will be anhydrous and white, but will become of a reddish-brown when dissolved in water. It cannot be made to crystallize, but affords, upon evaporation, a brown deliquescent mass, soluble in alcohol. Its taste is highly astringent. It is composed of

$1\frac{1}{2}$ equivalent of	sulphuric acid . .	60
1 ditto	per-oxide of iron .	40
		100

This is another instance of the acid of a salt being in proportion to the oxygen of the base, the more remarkable on account of the half equivalent of the oxide (§ 293.) requiring an additional half equivalent of the acid for its saturation.

Sulphate of Potash.—88.
(1 S. 40 + 1 P. 48.)

(§ 423.) This salt may readily be prepared by decomposing carbonate of potash by sulphuric acid. It is produced on a large scale in the manufacture of nitric acid, of which it constitutes the residue (§ 72.). Its taste is saline and bitter; it crystallizes in six-sided prisms, which contain no water of crystallization, and suffer no change by exposure to air. It is not very soluble, and requires sixteen times its weight of cold water and five of boiling water for its solution. It decrepitates at a red heat, and is volatilized, without decomposition, at a still higher temperature. If hydrogen gas be passed over it at a red heat it will be decomposed; the oxygen both of the acid and base will be abstracted, and sulphuret of potassium remain. It also produces sulphuret of potassium by calcination, at a high heat, with one-fifth of its weight of charcoal. When two parts of this salt and one of lamp-black are heated to redness in a

phial coated with clay, and the air carefully excluded during the process, a powder is obtained which takes fire upon exposure to the air; a phenomenon owing to the heat evolved by the rapid absorption of oxygen and the consequent ignition of the sulphur and charcoal.

Bisulphate of Potash.—128.
(2 S. 80 + 1 P. 48.)

(§ 424.) By pouring sulphuric acid into a hot solution of sulphate of potash, the base will combine with a second equivalent of the acid. The bisulphate may be obtained in prismatic crystals or in the form of delicate needles. Its taste is acid, and it is much more soluble and fusible than the foregoing compound. Alcohol throws down from its aqueous solution the neutral sulphate of potash. It is sometimes used for cleansing works in brass.

Sulphate of Soda.—72.
(1 S. 40 + 1 So. 32.)

(§ 425.) The sulphate of soda may be formed by the direct combination of the acid and base, but is abundantly produced in the manufacture of muriatic acid by the decomposition of common salt (§ 86.). It crystallizes, from its aqueous solution, in four-sided prisms, which contain ten equivalents of water of crystallization. Of these it parts with a very large proportion by efflorescence in a dry atmosphere. Its taste is saline and bitter, and it has been long known in medicine by the name of *Glauber's Salt.* It is very soluble in water, but presents a very singular irregularity in this respect. Its solubility increases to a certain point, and then diminishes. It increases to 92°, which is the maximum point, and decreases to 215°. It is insoluble in alcohol. It may be deprived of its water of crystallization by heat, and then resists further decomposition. The taste of the anhydrous salt is acrid and hot, and it absorbs moisture with great avidity. It may be made, consecutively to undergo both the aqueous and igneous fusion.

A bisulphate of soda may be formed by a similar process to that by which the analogous salt of potash is produced.

Sulphate of Lime.—86.
(1 S. 40+1 L. 28+2 W. 18.)

(§ 426.) The sulphate of lime is an abundant product of nature, and is known by the names of selenite, alabaster, gypsum, and plaster-stone. It may easily be formed by art, and obtained in silky crystals, which require 433 parts of water for their solution. At a dull red heat, all the varieties lose their two equivalents of water, and fall into a white powder, which is called plaster of Paris. It again rapidly absorbs water when presented to it, and returns to its former chemical composition, *setting* into a firm and durable mass. The waters of springs, which are commonly designated as *hard,* owe their unfitness for domestic purposes chiefly to this salt in solution. It is insoluble in alcohol or the acids. At a white heat it may be melted into a species of white enamel.

The well-known uses of this salt in the arts are various. It is employed as the basis of various cements and stuccoes, and when worked up with a proportion of gelatine or animal glue, is used for the imitation of various marbles and porphyries of the utmost beauty in our buildings. It is used for mouldings, and for taking casts of the greatest delicacy; and is also of service as a manure on particular kinds of soils, and for particular crops.

Sulphate of Baryta.—118.
(1 S. 40+1 B. 78.)

(§ 427.) The sulphate of baryta is also an abundant natural product, and is easily formed artificially by double decomposition of the soluble salts of the same base. If sulphuric acid be poured upon pure baryta, the heat produced is so great as to cause ignition. It is perfectly insoluble in water, alcohol, or any acid. It is in natural crystals, but can only be produced by art in the form of a ponderous white powder. At a high temperature it fuses into an opaque white enamel, and has been employed in the manufacture of a particular kind of fine earthen ware. It is also used as a pigment, under the name of *permanent white.*

The sulphate of baryta may be converted into a sulphuret by calcination with charcoal.

The extreme insolubility of this salt renders the soluble salts of baryta most delicate tests of the presence of sulphuric acid (§ 415.); and it has been calculated that the millionth part of any sulphate in solution may be detected by this means, by the formation of a distinct white cloud.

Sulphate of Magnesia.—60.
(1 S. 40 + 1 M. 20.)

(§ 428.) The sulphate of magnesia has long been known by the name of *Epsom salts:* it being a principal ingredient in the saline springs of that town, as well as of those of other places. It is now commonly obtained from the residue of sea-water, after common salt has been separated from it by evaporation. When strong sulphuric acid is poured upon magnesia, intense heat is excited by their mutual action, and sometimes ignition. It may be obtained in four-sided prismatic crystals, which contain seven equivalents of water, which may be expelled by a red heat, without any further decomposition. The taste of this salt is slightly bitter, and it is largely used in medicine. It may be made to undergo both the aqueous and igneous fusion. It is soluble in its own weight of water at 60°, and in three-fourths of its weight 212°. When calcined with charcoal it does not afford a sulphuret like the other salts of this class which we have described, but magnesia and sulphur are the products.

Sulphate of Alumine.—58.
(1 S. 40 + 1 A. 18.)

(§ 429.) The sulphate of alumine may be obtained by the direct combination of sulphuric acid, diluted with an equal bulk of water, and pure alumine. It is a salt of little importance, and assumes the form of lamellar crystals, with a pearly appearance, which contain a considerable proportion of water of crystallization. Its taste is astringent and sweet; it is taken up by double its weight of water at ordinary temperatures, and at a white heat it is completely decomposed.

Alum.

(§ 430.) The sulphate of alumine, which we have described above, is capable of combining with several other salts to form a class of double salts (§ 394.), to which the general name of *alum* has been given. Many of the other sulphates are also capable of forming double salts, but we have passed them by as possessing little interest. Alum, on the contrary, is a product of considerable commercial value, and much used in the arts.

Upon pouring into a concentrated solution of sulphate of alumine a strong solution of sulphate of potash, a precipitate will be formed, which is the double salt in question. It may be regarded as a compound of

3 equivalents of sulphate of alumine . . .	174 (§ 429.)
1 ditto sulphate of potash	88 (§ 423.)
25 ditto water	225
	487

It possesses a well known sweetish astringent taste, reddens vegetable blues, and is soluble in 5 parts of water at 60° F. It crystallizes in very perfect octohedral forms. When it is exposed to heat, it loses the whole of its water, and part of the acid is decomposed: it becomes very light and spongy, and is known by the name of burnt alum. When alum is strongly heated with minutely divided charcoal, a very remarkable product is obtained, which has long been known by the name of *Homberg's Pyrophorus.* The process is best conducted by mixing equal parts of flour or sugar with the powdered salt in an iron ladle, melting the mixture over a fire, and stirring it till dry. The mass should be reduced to powder, and introduced into a phial, coated with clay, and placed in a crucible of sand. It should then be heated red till a blue flame appears at the opening of the phial, which may be allowed to burn for about five minutes, when it must be removed from the fire, and the bottle carefully stopped. When a little of this powder is exposed to the air it spontaneously inflames. In this decomposition a sulphuret of potassium is formed by the deoxidation of the sulphuric acid and potash. The sulphate of alumine is also decomposed, but the alumine having no affinity for the sulphur, the latter remains in excess, and burns away when the sulphuret of potassium is ignited by the moisture which it absorbs from the air.

An alum is also produced by the substitution of sulphate of soda for the sulphate of potash. It is an efflorescent salt, and appears to contain more water of crystallization than the preceding; sulphate of ammonia may, likewise, take the place of the salts of fixed alkalies. It crystallizes exactly in the same form, but it is entirely decomposed by heat. Oxygen, sulphurous acid, and ammonia, are produced, and pure alumine remains behind.

Alum is of extensive use in dyeing and calico printing, in consequence of the

attraction of its base for colouring matters.

It is prepared on a large scale by roasting and lixiviating certain schists or clays which contain pyrites or sulphuret of iron. To the lixivia a proper proportion of sulphate of potash is added, and the double salt is obtained by evaporation and crystallization.

The Hypo-sulphites.

(§ 431.) We have stated (§ 120.) that the hypo-sulphurous acid cannot be separated from the bases with which it is combined, without undergoing decomposition; this class of salts is, nevertheless, of constant composition and well characterized. They are nearly all soluble, but a few of them sparingly so. They have a sulphurous taste. They are more easily decomposed by heat than even the sulphites; a sulphate is produced and the excess of sulphur separated. They are not changed by contact with the air at common temperatures. When a stronger acid is poured into the solution of a hypo-sulphite, the liquid does not at first become troubled, but after a little time sulphur precipitates: the hypo-sulphurous acid is disengaged, but at the same moment is resolved into sulphurous acid and sulphur. There are nearly as many hypo-sulphites as there are bases; but they are of little interest and have not been applied to any use.

Hypo-sulphite of Potash.

(§ 432.) The hypo-sulphite of potash may be formed, by decomposing hydro-sulphuret of potash (a salt presently to be described), by sulphurous acid and evaporating the solution. Acicular crystals may thus be obtained of a cooling, but bitter taste, which attract moisture from the air. If its solution be carefully evaporated to dryness, and the heat gradually raised, the salt takes fire and burns like tinder. By exposure to air it first becomes converted into sulphite and afterwards into sulphate of potash. Its solution readily dissolves moist chloride of silver.

Hypo-sulphite of Lime.

(§ 433.) The hypo-sulphite of lime may be procured by passing sulphurous acid through an aqueous solution of sulphuret of lime. By filtration and evaporation, at a temperature not exceeding 140° F., it may be obtained in crystals. It is decomposed by a temperature of 212° F. The crystals are soluble in water, but not in alcohol: they consist of

1 equivalent of lime	28
2 do. hypo-sulphurous acid .	48
6 do. water	54
	130

Hypo-sulphite of Baryta.

(§ 434.) The hypo-sulphite of baryta is thrown down on pouring muriate of baryta into a strong solution of hypo-sulphite of lime: it is in the form of a white powder, which is soluble, without decomposition, in muriatic acid; and at a low heat takes fire.

Hypo-sulphite of Silver.

(§ 435.) This salt is composed by dropping a weak solution of nitrate of silver into a dilute solution of hypo-sulphite of soda (which may be formed, by an analogous process to the hypo-sulphite of potash). It forms a grey precipitate, and the supernatant liquid tastes intensely sweet; which is the more remarkable, as both the original salts are nauseously bitter. Hence we may argue—"how little we know of the way in which bodies affect the organs of taste. Sweetness and bitterness, like acidity, seem to depend upon no particular principle, but to be regulated by the state of combination in which the same principles exist at different times."

Hypo-sulphite of silver is also produced whenever the chloride of silver is taken up by a solution of any of the hypo-sulphites, a solution which most of them are capable of effecting. The combination is at all times characterized by its peculiar sweet taste, which is entirely free from any metallic flavour.

The Hypo-sulphates.

(§ 436.) The hypo-sulphates may easily be recognized by pouring upon them strong sulphuric acid: the hypo-sulphuric acid (§ 121.) is thus disengaged and decomposed by the heat evolved with extrication of sulphurous acid. They are not affected by exposure to the air. When strongly heated with combustible bodies, they afford the same products as the sulphates. No precipitate is formed when solutions of any of the salts of baryta are added to them; as the hypo-sulphate of baryta, unlike the sulphate, is a soluble salt.

Hypo-sulphate of Manganese.

(§ 437.) We have stated in another place (§ 121.), that by passing sulphu

rous acid through water in which finely-pounded peroxide of manganese is suspended, the peroxide yields part of its oxygen to the acid, and converts one portion into sulphuric and another into hypo-sulphuric acid. Sulphate and hypo-sulphate of manganese are both produced; and by pouring lime into the mixed solution, the oxide of manganese is thrown down with an insoluble sulphate of lime, while a soluble hypo-sulphate of lime is left in solution.

The solution of hypo-sulphate of manganese affords a deliquescent salt by evaporation.

Hypo-sulphate of Baryta.

§438.) The hypo-sulphates of baryta, potash, soda, &c., may easily be obtained from the hypo-sulphate of lime above described; as all these substances precipitate the lime. The hypo-sulphate of baryta is a brilliant salt, and crystallizes easily. It is composed of 1 equivalent of acid and 1 of base, and when in crystals contains 8 equivalents of water. It is readily soluble. It is from this salt that the pure hypo-sulphuric acid (§ 121.) is produced, and the process will now be readily understood. Sulphuric acid is carefully dropped into its solution, in quantity just sufficient to precipitate all the baryta, and the hypo-sulphuric acid remains in the liquid. The acid is decomposed by a heat below that of boiling water.

The Hydro-sulphurets, or Sulphurets.

(§ 439.) Sulphur, we have seen (§ 122.), is capable of acidification by its union with hydrogen as well as with oxygen; and it is again, with reference to our general remarks upon the hydro-acids (§ 362.), that we shall proceed to characterize the combinations which this acid forms with the several bases.

When the sulphurets are soluble in water, (in which case they are commonly designated as hydro-sulphurets, and are considered as combinations of sulphuretted hydrogen with the oxides,) they are decomposed by the acids, and give rise to a disengagement of sulphuretted hydrogen. They precipitate all metallic substances, but are in their turn decomposed by chlorine, bromine, and iodine, all of which have a greater affinity to the bases than sulphur. The solutions of the hydro-sulphurets are all nearly colourless, but by exposure to air they absorb oxygen; part of the hydrogen is detached from the acid, which is thus converted into bi-sulphuretted hydrogen, the combinations of which are of a yellow colour.

The insoluble sulphurets may be recognised by treating them with diluted nitric, or weak nitro-muriatic acid, when sulphur will be precipitated.

Sulphuret of Potassium, or Hydro-sulphuret of Potash, and Sulphurets of the other Alkaline Metals.

(§ 440.) When 40 parts of potassium are heated with 16 of sulphur, in a tube from which the atmospheric air has been exhausted, they act very energetically upon each other, with the extrication of much light and heat: the resulting compound, sulphuret of potassium, is of a brownish grey colour. The same compound may be obtained on a large scale by passing hydrogen through a redhot tube containing sulphate of potash. The hydrogen unites with the oxygen both of the acid and the base; water is formed, and the sulphur left in combination with the metal. It is deliquescent, and not very inflammable.

It readily dissolves in water, and affords a colourless solution. A similar solution is obtained by passing sulphuretted hydrogen into a solution of potash in water. If the process be continued to saturation, a *bi*-hydro-sulphuret will be produced, which may be restored to the neutral state by the addition of a quantity of potash equal to that originally employed. Hydro-sulphuret of potash may therefore be regarded as sulphuret of potassium in solution.

Sulphuret of potassium is composed of

1 equivalent of sulphur .	16
1 ditto potassium . .	40
	56

Hydro-sulphuret of potash is composed of

$$\begin{array}{lcl}
\text{1 equivalent of sulphuretted hydrogen} & = 17 = & \left\{\begin{array}{ll}\text{1 sulphur} & = 16 \\ \text{1 hydrogen} & = 1\end{array}\right. \\
\text{1 ditto potash} \quad . \quad . & = 48 = & \left\{\begin{array}{ll}\text{1 oxygen} & = 8 \\ \text{1 potassium} & = 40\end{array}\right. \\
 & \overline{65} & \qquad\qquad\quad \overline{65}
\end{array}
\qquad \left.\begin{array}{l}\text{1 hydrogen} = 1 \\ \text{1 oxygen} = 8\end{array}\right\} \text{1 water} = 9$$

Bi-Hydro-Sulphuret of Potash.

(§ 441.) The hydro-sulphuret above described is not susceptible of crystallization, but when sulphuretted hydrogen is passed into solution of potash to saturation, crystals may be obtained of the form of six-sided prisms, which are deliquescent and soluble both in water and alcohol. This bi-sulphuret has an alkaline bitter taste, and notwithstanding its being a *bi*-salt changes yellow vegetable colours to red.

(§ 442.) Analogous compounds, with sulphur and sulphuretted hydrogen, may be formed with the other alkaline metals and their oxides, but their individual description need not detain us. They may all be prepared by passing an excess of sulphuretted hydrogen gas through these bases dissolved or diffused in water.

Sulphurets of Iron and other Non-Alkaline Metals.

(§ 443.) The proto-sulphuret of iron (§ 296.) is precipitated by adding any of the alkaline hydro-sulphurets to solutions of the proto-salts of iron.

The bi-sulphuret (§ 297.) may be procured by passing a current of sulphuretted hydrogen over peroxide of iron at a temperature just below redness. In general most of the solutions of the non-alkaline metals form precipitates with sulphuretted hydrogen or the hydro-sulphuretted alkalies, and when the metal is susceptible of two degrees of oxidation sulphurets of both may be obtained proportional to the degree of oxidation, as the oxygen decomposes a quantity of sulphuretted hydrogen equivalent to its own amount. These precipitates are distinguished by various colours. After they have been dried at common temperatures, they give off water by heat, and they may be considered as hydrated sulphurets of the metals or hydro-sulphurets of the oxides.

The following Table exhibits the colours of some of the precipitates of the metals as produced by hydro-sulphuretted hydrogen and hydro-sulphuret of ammonia (§ 193.).

Table V.

Metal.	Solution.	Sulp. Hydrogen.	Hyd. Sul. Amm
Mercury......	Acid Nitrate.....	Black	Black
Do.........	Pernitrate ..	Do...........	Do.
Do.........	Corrosive Sublimate	Brown	Do.
Silver........	Nitrate	Black........	Brown
Gold.........	Muriate	Do...........	Yellow
Platinum	Muriate	Deep Brown ..	Pale Brown
Nickel	Sulphate........		Black
Lead.........	Muriate & Nitrate	Black........	Brown & Black
Copper.......	Protomuriate	Deep Brown ..	Brown
Do.........	Pernitrate	Black........	Brown & Black
Bismuth......	Tartrate of Bismuth & Potash	Deep Brown ..	Deep Brown
Titanium.....	Acid Muriate		Black
Do.........	Neutral Sulphate.		Green
Cobalt	Muriate.........		Copious Black
Uranium	Sulphate	Brown	Blackish Brown
Antimony	Tartrate of &Potash	Orange Red ..	Bright Orange
Chromium....	Muriate.........		Green
Arsenic		Yellow.......	Yellow
Tin..........	Acid Protomuriate	Brown	Orange
Iron	Protosulphate....		Black
Do............	Permuriate	Black........	Do.
Zinc	Muriate		Straw-coloured
Cadmium	Muriate	Yellow.......	Yellow
Manganese ...	Protomuriate		Ochre Yellow.

The colour of these precipitates is often employed to distinguish the various metals in solution.

The Sulphuretted Hydro-sulphurets.

(§ 444.) We have observed (§ 339.) that the colourless hydro-sulphurets are decomposed by exposure to air, the oxygen of which abstracts part of their hydrogen, and leaves the bases combined with bi-sulphuretted hydrogen (§ 124.), and of a yellow colour. These compounds may be distinguished by the name of sulphuretted hydro-sulphurets, as the title of bi-hydro-sulphurets would confound them with the combinations of two equivalents of sulphuretted hydrogen (§ 441.). They may be prepared by digesting sulphur in solutions of the alkaline hydro-sulphurets. They are also formed when alkalies, or the alkaline earths, are boiled with sulphur and water; but in this case they are mixed with other salts, the oxygen of part of the base acidifying a portion of the sulphur and uniting with another part.

The salts of bi-sulphuretted hydrogen absorb oxygen rapidly from the air, and are gradually converted into hypo-sulphites, a change which is at once effected by sulphurous acid. Dilute muriatic and sulphuric acids produce in them a deposition of sulphur and evolution of sulphuretted hydrogen gas. When these solutions are poured into solutions of the non-alkaline metals, sulphuretted hydrogen is given off, and simple sulphurets are precipitated.

Sulphuretted Hydro-sulphuret of Potash.

(§ 445.) If 40 parts of potassium be heated, out of the contact of air, with 32 parts of sulphur—instead of 16, as directed above (§ 440.)—a brown fusible substance will be obtained, permanent at a red heat. This bisulphuret of potassium is converted, by the action of water, into a solution of sulphuretted hydro-sulphuret of potash.

The bi-sulphuret of potassium is composed of

2	equivalents of	sulphur	32
1	ditto	potassium	40
			72

The sulphuretted hydro-sulphuret of

$$\begin{array}{lll}
1 \text{ equivalent of bi-sulphuretted hydrogen } 33 = \begin{cases} 2 \text{ sulphur} & 32 \\ 1 \text{ hydrogen} & 1 \end{cases} & & \\
1 \text{ ditto potash } 48 = \begin{cases} 1 \text{ oxygen} & 8 \\ 1 \text{ potassium} & 40 \end{cases} & & \left.\begin{matrix}1\\8\end{matrix}\right\} = 1 \text{ water} = 9. \\
\quad 81 \qquad\qquad 81 & &
\end{array}$$

The aqueous solution is of a yellow colour; and when diluted acids are added to it, sulphuretted hydrogen is given off, and sulphur precipitated (§ 446.). These compounds are capable of taking up additional, but variable proportions of sulphur; but it is uncertain whether any definite compounds are produced, except such as are analogous to those which we have already noticed.

Chapter XIX.

On the Phosphates—Phosphites—and Hypo-phosphites.

(§ 447.) The salts formed by the phosphoric acid (§ 134.) may be distinguished from those of the volatile acids by pouring upon them sulphuric acid, when no gaseous product will be given off; and the only salts of fixed acids with which they are liable to be confounded are the sulphates, borates, and arseniates, each of which may be identified by very distinct characters. The phosphates, with fixed bases, sustain a red heat without decomposition, but are all fusible at a high temperature. The neutral phosphates of potash, soda, and ammonia, are abundantly soluble in water, but all the others very sparingly; they are, however, without exception, taken up without effervescence by excess of phosphoric or nitric acids, from which they are again precipitated, without change, by ammonia.

When lime-water is added to any soluble phosphate, a gelatinous white precipitate is formed, which much resembles a precipitation of alumine.

The neutral phosphate of lead is insoluble in water, but soluble in acids. When fused before the blowpipe, (a metallic tube with a lateral jet, by which a stream of air from the mouth can be directed upon the flame of a candle in such a manner as to concentrate its force upon minute particles of any matter which it may be wished to expose to an intense heat,) it fuses, and, when suffered to cool, sets into a very distinct polyhedral form; and at the same in-

stant becomes incandescent. This very remarkable character may be generally applied to distinguish the phosphates. If the salt should be soluble, a solution of any salt of lead will precipitate the insoluble phosphate of that metal; and, if insoluble, the salt of lead may be added to it with excess of any acid, as the nitric, when the precipitate may be treated as above.

Phosphate of Soda.—60.

(1 P. 28 + 1 S. 32.)

(§ 448.) The phosphate of soda may be directly prepared by neutralizing phosphoric acid with soda: a slight excess of the alkali should be allowed to predominate. The salt forms in rhomboidal crystals, which contain twelve equivalents of water. Its taste is cool, saline, and devoid of bitterness, and on this account is often employed in medicine instead of sulphate of magnesia. When exposed to the air it effloresces; but although the crystals on this account become opaque, they do not part with the whole of their water. At a high temperature, however, the whole may be driven off, the salt first undergoing the aqueous, and afterwards the igneous fusion.

Phosphate of soda is manufactured on a large scale by neutralizing the phosphoric acid, procured by the action of sulphuric acid on burned bones (§ 130.), with carbonate of soda.

A bi-phosphate of soda may be formed, consisting of two equivalents of acid, one of base, and four of water, which crystallizes in a very different form from the preceding.

A double phosphate of soda and ammonia may also be easily prepared by dissolving one equivalent of muriate of ammonia and two of phosphate of soda in boiling water. It has long been known by the name of *microcosmic salt*, and is much employed as a flux in experiments with the blowpipe. It parts with its ammonia and its water at a high temperature, and is converted into the very fusible bi-phosphate of soda.

Phosphates of Lime.

(§ 449.) There is a considerable difference of opinion amongst chemists as to the number of combinations which the phosphoric acid forms with lime. By pouring phosphate of soda into muriate of lime, a white precipitate is obtained, which is the neutral phosphate of lime, composed of 1 equivalent of acid, 1 of base, and 2 of water. It is precipitated in the form of small crystals, attached together by their extremities in a divergent form.

If, on the other hand, muriate of lime be very gradually added to phosphate of soda, leaving the latter in excess, a very different precipitate will be obtained, consisting of sub-phosphate of lime, corresponding in composition to the residue of calcined bones (§ 130.). A bi-phosphate of lime may also be formed by saturating the neutral phosphate with phosphoric acid. The solution by spontaneous evaporation crystallizes in the form of small pearly plates.

All the phosphates of lime are decomposed by sulphuric acid, which forms sulphate of lime, and disengages the phosphoric acid.

Phosphate of Lead.—140.

(1 P. 28 + 1 L. 112.)

(§ 450.) The phosphate of lead cannot be directly formed on account of the insolubility, both of the base and its resulting combination with the acid. However minutely the former may be mechanically divided, the action can only be superficial. It may, however, be readily produced by double decomposition. By mixing solutions of nitrate of lead and phosphate of soda, it is precipitated in the form of a yellowish white powder, which is insoluble in water, but soluble in nitric acid, and in alkaline solutions. It readily melts by the application of heat, and, upon cooling, crystallizes in so singular a manner as to furnish a ready method of detecting the presence of any phosphate, by first converting it into this salt (§ 447.).

The phosphate of lead exposed to a white heat, in contact with charcoal, is readily decomposed, and phosphorus is produced; but the metallic phosphates, in general, are converted into phosphurets by sufficient elevation of temperature.

The Phosphites.

(§ 451.) The salts which are formed by the phosphorous acid (§ 132.) have the same general characters as the phosphates; into which class they are converted by the application of heat. They are of very little importance: three only of them are very soluble; namely, the phosphites of ammonia, potash, and soda. They may be formed by pouring phosphorous acid into solutions of these

bases till they are neutralized. The solution must be evaporated till it attains the temperature of about 120°, when a separation will take place: the neutral salt will be deposited, and a salt with excess of acid remain dissolved.

The Hypo-phosphites.

(§ 452.) The salts of the hypo-phosphorous acid (§ 135.) are analogous to those of the hypo-sulphurous (§ 436.), and possess but little interest. They are all soluble in water. When heated, they give off phosphuretted hydrogen gas from the decomposition of the water which they contain, and they are converted into phosphates. When thrown upon ignited coals, they burn with a bright yellow flame. Solutions of these salts, exposed to the atmosphere, absorb oxygen, and are converted into phosphates.

Hypo-phosphite of Baryta.

(§ 453.) A compound of barium and phosphorus, or a *phosphuret of barium*, may be formed by passing the vapour of phosphorus over heated baryta. The action is intense—phosphate of baryta is produced; and the phosphuret of the base, of a metallic lustre. When thrown into water, phosphuretted hydrogen is given off, and spontaneously inflames in the air, and a hypo-phosphite of baryta remains in solution. By evaporation it may be collected in the form of prismatic crystals. It is from the solution of this salt that the hypo-phosphorus acid is obtained as already described (§ 135.). The baryta is carefully precipitated by sulphuric acid, and the acid disengaged.

Chapter XX.

On the Carbonates and Borates.

(§ 454.) The carbonic acid (§ 156.) by its union with the different bases forms carbonates, bi-carbonates, and sesqui-carbonates, whose general properties very much resemble each other. When exposed to heat they all lose their acid, except the carbonates of potash, soda, and lithia; and the salts of these bases which contain more than one equivalent of carbonic acid, are reduced to the state of neutral carbonates by elevation of temperature. The carbonates of baryta and strontia require, however, an intense white heat for their decomposition; while those of lime and magnesia are reduced to the caustic state by a full red heat, and those of the other bases are decomposed at a less temperature. They are, without any exception, decomposed by a high heat when mixed with charcoal, which takes half the oxygen from the carbonic acid, and produces carbonic oxide.

They are universally decomposed by the acids with strong effervescence of carbonic acid, and are thus easily recognised.

All the combinations of the carbonic acid with potash, soda, and ammonia, are soluble in water; those of lithia but little so; and those of the other bases are insoluble: an excess of carbonic acid in solution will, however, take up more or less of all the salts of this class.

The soluble carbonates are but little taken up by alcohol.

Carbonate of Potash.—70.

(1 C. 22+1 P. 48.).

(§ 455.) This salt is obtained in an impure form by burning vegetables, which do not grow in a soil impregnated with sea salt, lixiviating their ashes, and evaporating the solution to dryness. In this state it is found in commerce under the names of potash and pearl-ash, and is largely employed in the manufactures of glass and soap. It may be prepared in greater purity by heating cream of tartar (bi-tartrate of potash, hereafter to be described) to redness: a pure carbonate of potash mixed with charcoal is the result of this operation. It may be purified by dissolving it in water, filtering and evaporating to dryness in a silver vessel.

Its taste is strongly alkaline, but not caustic, and it changes vegetable colours to green. It is very soluble in water, which will take up its own weight of the salt; and it deliquesces rapidly in the air. It may be obtained in crystals with difficulty, which contain two equivalents of water. It is insoluble in alcohol, and fuses at a red heat without change. If steam be passed over carbonate of potash in a redhot tube, its carbonic acid will be expelled, and a hydrate of potash formed; and on the other hand, if a current of carbonic acid gas be passed over the hydrate, the water will be displaced, and the carbonate reproduced. This is a consequence of the law to which we have previously adverted (§ 365.), by which two acids divide a base between them. The water, by its affinity for the potash, performs the part of an acid, and, when applied in

excess will totally displace the limited quantity of carbonic acid in the carbonate; and on the contrary, when the carbonic acid is in excess, it will finally expel the limited amount of water in the hydrate. A few of the metals and charcoal, at very high temperatures, decompose this salt with the production of potassium.

Bi-Carbonate of Potash.—92.

(2 C. 44 + 1 P. 48.)

(§ 456.) When carbonic acid is passed through a solution of potash, or of the carbonate, to saturation, the bi-carbonate is formed. In crystals, it contains one equivalent of water. Its taste is slightly alkaline, and it acts but weakly upon vegetable colours. It requires four parts of water at 60° for its solution. It parts with a portion of its acid at the mere temperature of ebullition, and is converted into the carbonate by a red heat.

Sesqui-Carbonate of Potash.—81.

($1\frac{1}{2}$ C. 33 + 1 P. 48.)

(§ 457.) When a solution of the bi-carbonate of potash is boiled till carbonic acid is no longer given off, it forms, on cooling, deliquescent crystals, which are insoluble in alcohol. They contain six equivalents of water, and one and a half equivalent of acid to one of the base. The same salt may be procured by dissolving 100 parts of carbonate, and 131 parts of bi-carbonate of potash in water.

Carbonate of Soda.—54.

(1 C. 22 + 1 S. 32.)

(§ 458.) Impure carbonate of soda is obtained by lixiviating the ashes of sea-weeds, as carbonate of potash is procured from the ashes of land-plants. It may be obtained pure by calcining a salt called the acetate of soda, dissolving the product in water, and filtering and evaporating the solution. It is soluble in twice its weight of water at 60° and in less than its own weight at 212°. Its taste is very alkaline, and it turns vegetable blue colours to green. It readily forms crystals which contain 10 equivalents of water. It effloresces in the air, parting with a portion only of its water of crystallization; and it undergoes aqueous fusion upon exposure to heat. Like the carbonate of potash, it may be decomposed by vapour of water at a red-heat, and the resulting hydrate is reconverted into a carbonate by carbonic acid. Carbonate of soda is largely employed in the arts, and particularly in the manufactures of soap and glass.

(§ 459.) When excess of chlorine is passed into solutions of either the carbonate of potash or soda, the carbonic acid is commonly displaced, and chlorides and chlorates formed: but by peculiar management chlorine may be combined with carbonate of soda without decomposition. This solution has been called *disinfecting soda liquid*, from the uses which have been made of it, and which are analogous to those described of the chloride of lime (§ 390.). This solution is saline and astringent, and it first reddens and afterwards bleaches paper tinged with turmeric. It gives out no chlorine by ebullition; but when exposed to the air, this element, to which it owes its efficacy, gradually escapes, and the carbonate of soda remains.

Bi-Carbonate of Soda.—76.

(2 C. 44 + 1 S. 32.)

(§ 460.) The bi-carbonate of soda is formed by saturating soda, or its carbonate with carbonic acid. During the operation it is deposited in small crystals, which contain 2 equivalents of water. Its taste is slightly alkaline, and it is much less soluble in water than the preceding salt. It does not effloresce in the air. It is decomposed by heat, and passes to the state of sesqui-carbonate.

Sesqui-Carbonate of Soda.—65.

($1\frac{1}{2}$ C. 33 + 1 S. 32.)

(§ 461.) This salt is not only formed as above, but occurs abundantly in nature. It is imported in large quantities from the coast of Barbary, in Africa, where it is collected by the natives, under the name of *trona*. A very considerable soda lake also exists in the province of Maracaybo, in South America, from which this salt is fished up in very considerable masses.

Carbonate of Baryta.—100.

(1 C. 22 + 1 B. 78.)

(§ 462.) When baryta water is added to solutions of the carbonates of soda or potash it abstracts their acid, and carbonate of baryta is precipitated in the form of a white powder, which is nearly insoluble in water. It occurs native in crystals. It is destitute of taste or smell, but is very poisonous. It contains no water of crystallization, but may be melted into a white enamel by a very high degree of heat. It may be

decomposed with the assistance of charcoal; the carbonic acid is decomposed and expelled, and caustic baryta remains.

This carbonate may also be decomposed at a red heat by steam, and pure hydrate of baryta may be thus produced. It dissolves very sparingly in a solution of carbonic acid in water.

Carbonate of Lime.—50.
(1 C. 22+1 L. 28.)

(§ 463.) CARBONATE of lime is composed of 1 equivalent of acid, and 1 of base; and even when in crystals, as it often occurs in nature, contains no water. It is probably the most abundant compound upon the face of the earth. It forms the principal ingredient of chalk, and all the varieties of marble, oolite, and limestone. It is an abundant product of the animal, and is not deficient in the vegetable, kingdom. It is insoluble in pure water, and possesses no taste: it is, however, taken up by carbonic acid, and in this manner is found in various springs, as those of Matlock. As the volatile acid escapes, the carbonate of lime is deposited upon surrounding objects, and hence the origin of petrifying wells.

Carbonate of lime is decomposed by a red heat, and it is thus that limestones and chalk are burned into lime. Under a pressure sufficient to prevent the escape of the gas, carbonate of lime has been melted without decomposition.

Carbonates of Magnesia.

(§ 464.) THE neutral carbonate of magnesia cannot be obtained in an unmixed state by art, but occurs as a mineral product in the East Indies, in the form of a massive, hard, white substance, exhibiting a conchoidal fracture with translucent edges. It slowly dissolves in acids, and is composed of

1	equivalent of	magnesia . .	20
1	ditto	carbonic acid .	22
			42

When the carbonated alkalies are added to a solution of sulphate of magnesia, a white, insipid, insoluble powder is precipitated, which appears to vary according to the circumstances under which it is formed, and to consist of different proportions of carbonate and hydrate of magnesia. It is very soluble in excess of carbonic acid; so much so, that the sulphate of magnesia is not precipitated at all when cold by the alkaline bi-carbonates, or by the sesqui-carbonate of ammonia. When a solution, however, of carbonate of magnesia in carbonic acid is allowed spontaneously to evaporate, small prismatic crystals are formed, which are composed of magnesia, carbonic acid, and water; but in what proportions is somewhat doubtful.

Carbonate of Iron.—58.
(1 C. 22+1 I. 36.)

(§ 465.) THE carbonic acid forms a definite compound with the protoxide of iron only. When its aqueous solution is digested with iron filings, a colourless solution of the proto-carbonate is formed; and when carbonate of potash is added to sulphate of iron, the same salt falls as a greenish-white precipitate. When exposed to the air it absorbs oxygen, peroxide of iron is produced, and carbonic acid given off. The carbonate of iron is not an uncommon ingredient of mineral waters, in which it is held in solution by excess of acid, and it occurs native, in nearly a pure state, crystallized in small imperfect rhomboids.

Carbonate of Copper.

(§ 466.) COPPER united to carbonic acid occurs in a native state, in the form of a beautiful green mineral, called malachite. It consists of

1	equivalent of	peroxide of copper	80
1	ditto	carbonic acid .	22
1	ditto	water	9
			111

A similar product may be artificially formed by adding carbonate of potash to sulphate of copper. When carefully dried it is of a green colour, and insoluble in water. An impure carbonate is also manufactured as a pigment, and called verditer, by decomposing nitrate of copper by chalk.

Carbonate of Lead.—134
(1 C. 22 + 1 L. 112.)

(§ 467.) THERE is but one known combination of carbonic acid and lead, and this is constituted of one equivalent of the acid and one of the protoxide. It may be immediately formed by adding an alkaline carbonate to nitrate of lead. The white precipitate which falls is tasteless, insoluble in water, but soluble

in solutions of the fixed alkalies. It is manufactured upon a large scale as a white paint by exposing sheet lead to the action of fumes of vinegar with access of air. The lead is thus at the same time oxidized and converted into a carbonate by the decomposition of the vegetable acid. The native carbonate of lead is one of the most beautiful of the metallic ores: it occurs in Cornwall in the form of delicate white needles, which are soft and very brittle.

The Borates.

(§ 468.) The affinities of the boracic acid (§ 183.) for the different bases is but weak; and, in ordinary circumstances, it is displaced by most of the other acids, and is thrown down in the form of pearly scales: but it is so fixed at a high temperature, that, at a red heat, it decomposes all salts, not excepting the sulphates, the acid of which is volatile. In general the borates are very sparingly soluble in water, except those of potash, soda, and ammonia. They are insoluble in alcohol, but are readily taken up by the different acids. They are not decomposed by heat, but are remarkably fusible in the fire, and form a transparent glass on cooling. By digesting any of these salts in a slight excess of strong sulphuric acid, evaporating to dryness, and boiling the residue in strong alcohol, a solution is formed, which has the property of burning with a green flame.

Borate of Soda, or Borax.—76.
(2 B. 44+1 S. 32.)

(§ 469.) The only salt of this class of any consequence is the borate of soda, commonly known in commerce by the name of *borax*. When crystallized it is composed of

2 equiv. of boracic acid	44
1 ditto soda . . .	32
8 ditto water	72
	148

Its taste is sweetish, alkaline, and astringent. When exposed to heat, it first undergoes the aqueous fusion, and afterwards, at a red heat, the igneous. On cooling, it assumes the appearance of a colourless, transparent glass, which speedily tarnishes in the air. It possesses the valuable property of dissolving and combining with all the metallic oxides, and by the different colours which they communicate to the glass, they may generally be distinguished before the blowpipe. With cobalt, the colour is deep blue; yellow with iron; and green, blue, or red with copper. It is soluble in twelve parts of water at 60° F., and in two parts at 212° F. It is chiefly used as a flux, and for the preparation of boracic acid. Muslin and other articles of apparel may be rendered almost incombustible by steeping them in a solution of borax: when dry they cannot afterwards be easily inflamed. This salt is imported from India, where it is found native in an impure state, and is called *tincal*. It occurs in some of the lakes of Thibet and Persia, and is extracted by evaporation. All the other borates may be formed from this salt by double decomposition.

Chapter XXI.

On the Salts of the Metallic Acids—the Antimonites and Antimoniates—the Chromates—the Arsenites and Arseniates.

(§ 470.) In the seven preceding chapters we have endeavoured to give clearly and succinctly the characters of the principal salts formed by the non-metallic acids enumerated in Table II., with the different salifiable bases; our limits will now oblige us to condense into the present one the leading properties of those of the most important metallic acids distinguished in Table IV. They are in general of rare occurrence, and few of them have been applied to useful purposes; there is, therefore, the less occasion to dwell upon them in detail.

The Antimonites and Antimoniates.

(§ 471.) We have seen (§§ 259, 261.) that antimony is capable of forming two electro-negative compounds with oxygen, which possess the property of uniting with the alkaline bases. The antimonious and antimonic acids have little activity, and are expelled from their combinations by the feeblest acids of the first class, not excepting the carbonic. The characters of the antimonites and antimoniates are so nearly the same, that they can only be distinguished by separating their acids: the acid of the first class gives off oxygen when exposed to heat, while that of the second affords none. The majority of these salts ar insoluble in water; those only are soluble whose bases are so likewise. The latter give an orange-yellow precipitate

with sulphuretted hydrogen. The readiest way of distinguishing the class, however, is to decompose them by an acid; to mix the disengaged antimonious or antimonic acid, which are insoluble in water, with charcoal, and expose it to heat, when a button of metallic antimony will be obtained. The antimoniate of potash may be easily procured by mixing one part of antimony with six parts of nitre in powder, and projecting the mixture into a red-hot crucible: a white mass will thus be obtained, which consists of the required salt with an excess of alkali. The latter may be washed away by cold water, as the antimoniate is insoluble in alkaline solutions. The antimoniate of potash may then be dissolved in boiling water. It does not crystallize, but forms pellicles by evaporation. Its taste is weakly alkaline. Acids precipitate from it the insoluble antimonic acid, in the state of a hydrate. The other antimoniates may be formed by pouring the solution of this salt into the different metallic solutions. The antimoniates of copper and of cobalt present us with a singular phenomenon: when they are dried and afterwards exposed to a dull-red heat, they suddenly become white hot. This sudden elevation of temperature is totally independent of the extraneous source of heat to which they are exposed, and is very difficult to explain.

The Chromates.

(§ 472.) All the salts of the chromic acid (§ 274.) are of a yellow, orange, or red colour: by mixing them with a little alkali, they afford, with the heat of the blowpipe, a beautiful green-coloured glass. This green colour of the oxide of chrome may also be developed by treating any chromate with muriatic acid and a little alcohol.

Chromates of Potash.

(§ 473.) If we neutralize chromic acid with potash, by evaporation of the solution, we shall obtain two distinct salts. The first which crystallizes will be a bi-chromate of potash, consisting of 2 equivalents of acid and 1 of base; the second, which is much more soluble, of 1 equivalent of acid and 1 of base. The latter, or *chromate of potash*, is procured in prismatic crystals of a fine lemon-yellow colour, and possesses a cool, bitter, disagreeable taste. It turns the yellow colour of vegetables red. When exposed to heat it is not decomposed, but assumes a tint of green from the formation of a minute portion of protoxide. Though very soluble in water, it is insoluble in alcohol, and does not contain any water of crystallization.

The *bi-chromate of potash* is much less soluble than the neutral chromate, and 100 parts of water only take up 10 of the salt. It forms beautiful tabular crystals of a rich red colour, which are anhydrous, and consist of 2 equivalents of the acid and 1 of the alkali. When exposed to heat they suffer decomposition; the neutral chromate is formed, mixed with oxide of chrome, from the deoxygenation of the excess of acid. The solution of this salt reddens vegetable blue colours.

The chromate of potash is manufactured on a large scale by heating to redness, with an equal weight of nitre, a mineral known by the name of chromate of iron, and which is a native compound of the oxides of iron and chrome. Chromic acid is thus generated, which combines with the alkali of the nitre. The mass obtained is digested in water, and the solution neutralized by nitric acid. By evaporation crystals of nitre are separated, and the residual liquid, by spontaneous evaporation, affords small crystals of the salt.

From the chromate of potash all the other chromates are easily obtained by double decomposition: the soluble salts of baryta, lead, protoxide of mercury, and silver, afford insoluble chromates of the same bases. The first two are yellow, the second orange-red, and the third deep red. Many of these salts are valuable as brilliant pigments; and a sub-chromate of lead, formed by boiling the neutral chromate with potash, is extensively used as a fine inalterable red in calico-printing.

The Arsenites and Arseniates.

(§ 474.) The only soluble compounds of the arsenious and arsenic acids (§§ 279, 280.) with the salifiable bases, are those of potash, soda, ammonia, and probably lithia; all the remainder are insoluble in water, but are taken up by an excess of their own acid, and still more readily by nitric acid. They are all decomposed by being heated to redness with charcoal, metallic arsenic being sublimed and easily recognised by its peculiar odour. The arseniates of the alkaline metals require a high temperature for this reduction, while those

of the common metals, such as lead, may be readily reduced in a glass tube by the heat of a spirit lamp.

The soluble arsenites, when perfectly neutral, afford a yellow precipitate of arsenite of silver, while the arseniates are characterised by a precipitate of a brick-red colour.

The arsenite of potash is uncrystallizable, and may be formed by boiling the acid in a solution of the alkali. When mixed with a solution of sulphate of copper, a precipitate is formed of a fine apple-green colour, which is used as a pigment. Although, under ordinary circumstances, this salt is a dangerous and violent poison, it is sometimes employed in very minute doses in medicine with success.

Chapter XXII.

On the Hydro-Fluates, or Fluorides—the Fluo-Silicates—and Fluo-Borates.

(§ 475.) Notwithstanding the obscurity which still veils the radicle of the acids (§ 348.), of whose compounds we have now to treat, the hydro-fluates of the bases, or the fluorides of the metals, (as, like the muriates or chlorides, they may be designated, according to the double view (§ 362.) which may be taken of their constitution,) form a distinct and well-characterized class of salts. When sulphuric acid is poured upon any of them and heated, white vapours of hydro-fluoric acid are given off, which may be recognized by the facility with which they corrode glass, even in very small quantities. They are not at all acted upon by combustible bodies. When they contain no water they readily fuse without change by the application of heat; but when they contain it, they undergo partial decomposition, and an oxide or sub-salt is formed. Those which are soluble do not precipitate nitrate of silver, and they do not give off fluorine when heated with sulphuric acid and oxide of manganese.

Hydro-Fluate of Ammonia.—36.

(1 H. 19 + 1 A. 17.)

(§ 476.) The hydro-fluate of ammonia may be prepared, by mixing in a platinum crucible 1 part of muriate of ammonia with 2.25 parts of fluoride of sodium (presently to be described), both in the state of a dry powder. By the application of a gentle heat, a double exchange takes place, and the hydro-fluate sublimes and condenses in small crystals upon the cool lid of the crucible. Chloride of sodium is at the same time formed.

The hydro-fluate of ammonia is very soluble in water, and slightly so in alcohol. The solution, by keeping, parts with a portion of its alkali, and is converted into a deliquescent bi-hydro-fluate. It corrodes glass even in its dry state, and its solution may be employed for etching on that substance. From the nature of its base, no ambiguity arises with regard to the constitution of this salt, which cannot, of course, be considered as a fluoride.

Hydro-Fluates of Potash.

(§ 477.) The hydro-fluoric acid forms two salts with potash, viz., a hydro-fluate and a bi-hydro-fluate. The former may be obtained by saturating the acid with potash and evaporating to dryness. It is deliquescent, and crystallizes with great difficulty. It has a sharp saline taste, dissolves silex, and acts upon glass. It bears an intense heat without change. By dissolving this salt in a further quantity of the acid the bi-hydro-fluate is obtained; it is crystallizable, soluble in water, and, when exposed to heat, on eequivalent of the acid is driven off, and the neutral hydro-fluate of potash remains.

Hydro-Fluates of Soda.

(§ 478.) Two combinations of the hydro-fluoric acid and soda may be obtained by the same method as the preceding salts. The neutral hydro-fluate crystallizes in cubes, like muriate of soda; is sparingly soluble in water, and corrodes glass.

The bi-hydro-fluate of soda crystallizes in transparent rhombohedrons; is also sparingly soluble in water, and possesses an extremely sour taste.

Fluoride of Calcium.—38.

(1 F. 18 + C. 20.)

(§ 479.) By digesting fresh-precipitated carbonate of lime in an excess of hydro-fluoric acid, a granular fluoride of calcium is formed, which is totally insoluble in water. A similar compound also is produced, in the form of a gelatinous mass, by precipitating a neutral salt of lime by any soluble fluoride. This salt is found in nature in the most beautiful forms, and is commonly known by the name of *fluor*, or *Derbyshire spar*. When exposed upon hot coals it decre-

pitates, and at the same time emits a beautiful phosphorescent light. The common varieties are used as a flux to metals, on account of its great fusibility, and the choice specimens are formed into splendid ornamental vases. It is also from this source that the hydro-fluoric acid is obtained (§ 349.).

The Fluo-Silicates.

(§ 480.) The combinations of the fluo-silicic acid (§ 350.) are not easily explained, and are still the subjects of controverted opinions. They have generally been considered as simple compounds of a complex acid and the bases; but there is reason to suppose that they may more accurately be regarded as double salts, consisting of two equivalents of hydro-fluate of silex and one equivalent of a hydro-fluate of some other base. Most of these salts are soluble in water; but those of potash, soda, lime, baryta, and yttria very sparingly so. They are characterized in general by a sour, bitter taste; they redden litmus paper, and are decomposed by a high temperature with extrication of fluo-silicic gas.

The Fluo-Borates.

(§ 481.) The compounds of the fluo-boric acid (§ 351.), with the salifiable bases, have not been hitherto examined. It has, however, been ascertained that it unites with ammonia in three proportions. When one measure of the acid gas is admitted to one of ammonia over mercury, a solid neutral compound results. One measure of the acid and two of the alkali form a liquid which will absorb an additional volume of ammonia and still remain in a fluid state.

Concerning the composition of all these three classes of salts considerable difficulty must be expected to exist, until the nature of the electro-negative element, fluorine (§ 348.), shall have been more fully developed by further investigation.

Chapter XXIII.

On the Hydro-Cyanates or Cyanurets—Cyanites and Fulminates—and on the Ferro-Cyanates and Sulpho-Cyanates.

(§ 482.) We come now to the classes of salts into the composition of which enter those acids which are produced by the compound radicle, cyanogen (§ 352.).

In treating of the compounds of the hydro-cyanic acid (§ 353.), we must not lose sight of its constitution as a hydro-acid (§ 362.). Thus, when potassium is brought into contact with it, *cyanuret of potassium* is undoubtedly formed, and hydrogen evolved; but this salt, when dissolved in water, may be considered either as a cyanuret of the metal or a hydro-cyanite of the oxide, and so with the other metals and bases.

Many of the cyanurets are soluble in water, as those of potassium, sodium, strontium, and calcium; several, however, are insoluble, as those of gold, silver, and copper.

The solutions of all the cyanurets have a strong alkaline reaction. The affinities of the hydro-cyanic acid are very weak, and it is expelled by all the other acids, not excepting the carbonic. When liberated by any of the stronger acids, it may be immediately recognized by its peuliar penetrating smell. The hydro-cyanates may also be distinguished by the deep blue precipitate which they occasion in salts of per-oxide of iron; to produce which, however, some of them require the assistance of an alkali. They are all subject to spontaneous decomposition. They have not been examined with the attention which their interest would seem to require.

Cyanuret of Mercury.—252.

(1 M. 200 + 2 C. 52.)

(§ 483.) We have already mentioned the process by which cyanuret of mercury is obtained (§ 173.). When pure it is colourless and inodorous, and possesses a very disagreeable metallic taste. It is highly poisonous. It crystallizes in the form of four-sided prisms, and is more soluble in hot than in cold water. It is converted by heat into metallic mercury and cyanogen.

Cyanuret of Potassium, or Hydro-Cyanate of Potash.

(§ 484.) Potassium heated in cyanogen absorbs the gas, and produces a yellowish-grey saline body, which is the cyanuret of potassium. It is soluble in water; and a similar solution is produced when solution of potash is dropped into hydro-cyanic acid. This salt is deliquescent, and possesses an alkaline taste, accompanied by something of the flavour and smell of the acid, whose poisonous properties it retains. It supports a high temperature in close vessels without undergoing decomposition.

Cyanuret of Iron.

(§ 485.) If a solution of cyanuret of potassium be poured into a solution of a salt of the protoxide of iron, a precipitate will be produced, and by filtration the cyanuret of iron may be collected. If an excess of the cyanuret be added, the precipitate will be redissolved and a new product formed, of which we shall presently have occasion to speak.

Similar results are produced when cyanuret of potassium is added to solutions of gold, silver, or copper.

THE CYANITES.

(§ 486.) The compounds of the cyanous acid (§ 354) are characterized by the facility with which their acid is resolved by boiling water into carbonic acid and ammonia. The effect takes place still more rapidly when it is attempted to displace the cyanous acid by means of another acid. It is immediately decomposed, and carbonic acid escapes with effervescence. The process for forming cyanite of potash has been already given (§ 384.). By double decomposition, from this salt may be obtained a soluble cyanite of baryta, and insoluble salts of lead, mercury, and silver.

THE FULMINATES.

(§ 487.) By dissolving 100 grains of mercury in one fluid ounce and a half of nitric acid of the specific gravity of 1.3, and adding to the solution, when cold, two ounces, by measure, of alcohol whose specific gravity is 0.849, and then warming the mixture, a brisk effervescence will take place, and a grey powder will precipitate, which is a fulminate of mercury. A similar compound may also be formed by treating silver in the same manner. These powders are dangerously explosive, and they ought not to be prepared without the greatest caution, and in very minute quantities. These effects have lately become, in some degree, familiar, from the use of the former in the preparation of copper caps for detonating guns. The fulminates explode at a temperature of about 300, from the slightest friction, and from the electric spark. The contact of concentrated sulphuric or nitric acid produces the same effect.

By digesting fulminate of silver in potash, 1 equivalent of oxide of silver is separated, and a double fulminate is formed, consisting of 2 equivalents of fulminic acid, 1 equivalent of oxide of silver, and 1 of potash. Similar compounds may be formed by substituting other bases, as baryta, lime, or magnesia for the potash. All these double fulminates may be obtained in crystals, and possess detonating properties.

THE CYANATES.

(§ 488.) The cyanic acid is of such recent discovery, that but little has been yet ascertained with regard to its combinations with the salifiable bases. The salts which it forms with the metallic oxides do not detonate.

THE FERRO-CYANATES, OR FERRO-CYANURETS.

(§ 489.) We have just stated (§ 485.) that cyanuret of iron may be dissolved by an excess of cyanuret of potassium, and a new salt is thus produced, which may be called the ferro-cyanuret of potassium. It is the same substance as that formed by directly combining ferro-cyanic acid (§ 361.) with potash, which being one of the hydro acids, its salts are liable to the same ambiguity as those of the rest of the class. The ferro-cyanates, or ferro-cyanurets, are not decomposed by the carbonic acid. They do not effervesce with the other acids, as that which they contain is not volatile. These which are soluble precipitate the proto-salts of iron of a white colour, and the per-salts of a deep blue.

Ferro-Cyanate of Potash, or Ferro-Cyanuret of Potassium.

(§ 490.) This salt, to which we have alluded above, may be prepared by digesting the per-ferro-cyanate of iron, presently to be described (Prussian blue), in potash, till the alkali is neutralized: a yellow liquid is formed, which yields crystals of the salt by evaporation. It is also manufactured on a large scale by igniting dried blood, or other animal matters, with potash and iron. By the mutual action of these substances at a high temperature, which cannot be explained till we come to treat of *Animal Chemistry*, ferro-cyanuret of potassium is generated.

It is a light yellow salt, crystallizing in large transparent tabular crystals which contain 3 equivalents of water. It has no smell, and its taste is slightly bitter, but very different from that of hydro-cyanate of potash. It is not altered by exposure to air, but it parts with its water of crystallization at a

high temperature. When heated to redness in close vessels decomposition ensues: nitrogen is disengaged, and cyanuret of potassium, mixed with carburet of iron, remains. It cannot be directly decomposed by the acids; but mercury, which has a very strong affinity for cyanogen, takes it from the salt. Oxide of mercury, put into a solution of ferro-cyanuret of potassium, renders it alkaline, and cyanuret of mercury is produced. It is employed for detecting the presence of several metals, with which it affords precipitates of various colours.

Ferro-Cyanate of Baryta.

(§ 491.) The process for forming the ferro-cyanate of baryta has been already described (§ 361.). It is from this salt that the ferro-cyanic acid may be prepared. It is sparingly soluble in cold water, but much more so in hot, and forms yellow crystals by evaporation.

Per-ferro-Cyanate of Iron.

(§ 492.) The common pigment called *Prussian blue* is a preparation of ferro-cyanic acid, united with the peroxide of iron. It is formed by adding ferro-cyanate of potash to solution of per-sulphate of iron. The precipitate which falls is of a beautiful deep blue colour, insoluble in water and alcohol, and tasteless. It is not acted upon by dilute sulphuric, nitric or muriatic acids. When kept in contact with iron filings, or exposed to the action of sulphuretted hydrogen, it loses part of its oxygen, and becomes white. It is, in fact, converted into proto-ferro-cyanate of iron, which may be directly formed as a white precipitate, by adding ferro-cyanate of potash to a solution of proto-sulphate of iron. It, however, regains its oxygen and colour by exposure to the air.

The common Prussian blue of commerce is impure, contains alumine, and is manufactured by adding to ferro-cyanate of potash, formed by calcining animal matters with potash, a solution of 2 parts of alum, and 1 of the sulphate of iron. The precipitate which falls is at first of a dingy-green colour, but, by frequent washings with dilute muriatic acid, acquires a fine blue tint.

The Sulpho-Cyanates.

Sulpho-Cyanate of Potash.

(§ 493.) The only salt of the sulpho-cyanic acid (§ 360,) which possesses any interest, is the sulpho-cyanate of potash. It is prepared by exposing to a moderate heat, short of redness, a mixture of equal weights of ferro-cyanate of potash and sulphur. The mixture fuses spontaneously, ignites and burns briskly, during which it should be well stirred. The dark-coloured residue, on being dissolved in water and filtered, affords a very pure sulpho-cyanate of potash. It is composed of 1 equivalent of the acid, and 1 of the alkali. When concentrated by evaporation, the solution yields crystals, which, when thoroughly dried, do not contain water or its elements, and may, therefore, be regarded as pure *sulpho-cyanuret of potassium.* They are, however, very deliquescent, and dissolve very readily in water. In form, taste, and fusibility, they greatly resemble nitre.

Chapter XXIV.

On the General Characters of Salts derived from their Bases. Conclusion of Inorganic Chemistry.

(§ 494.) In treating of the saline compounds, in the order of the acids, as we proposed (§ 366), we have endeavoured, previously to describing the individual species, to mark the leading characters of each groupe, derived from their electro-negative constituents: it remains for the completion of our plan that we briefly denote the properties dependent upon the electro-positive ingredient which characterize each class, in the order of their respective bases. For this purpose we shall again adopt a subdivision of the series, as an assistance to the memory, and to avoid the difficulty of having to search for any particular species through so long a catalogue. Such a convenient subdivision may be derived from the changes produced in their solutions by solutions of a saturated hydro-sulphuret, a carbonate, and sulphuretted hydrogen.

The first two classes thus formed will be, I., of those salts which are not precipitated by hydro-sulphuret of ammonia; and II., those which are. The former of these is subdivided into two groupes: 1st. those which are precipitated by carbonate of potash; 2d. those which are not precipitated. The latter, also, into two groupes: 1st. those which are precipitated by sulphuretted hydrogen; 2d. those which are not precipitated.

The following Table exhibits this arrangement, and the order in which we shall proceed to examine the *basic* characters of the salts.

TABLE VI.

Class	Character	Bases	Division	Character
CLASS I.	Hydro-sulphuret of ammonia does not precipitate salts of these bases.	Potash Soda Ammonia	1st DIVISION	Carbonate of potash does not precipitate salts of these bases.
		Lithia Baryta Strontia Lime Magnesia	2nd DIVISION	Carbonate of potash precipitates salts of these bases.
CLASS II.	Hydro-sulphuret of ammonia precipitates salts of these bases.	Alumine Manganese Zinc Iron Cobalt Nickel	1st DIVISION	Sulphuretted hydrogen does not precipitate salts of these bases.
		Chrome Tin Cadmium Antimony Bismuth Lead Copper Mercury Silver Platinum Gold	2d DIVISION	Sulphuretted hydrogen precipitates salts of these bases.

It may, however, be observed, that some of the above salts in the first division of the second class would give precipitates with sulphuretted hydrogen, if care were not taken to add it in excess: thus a slight precipitate would appear with zinc, and precipitates also with nickel and cobalt; but they immediately disappear by the addition of a little acid.

Salts of Potash.

(§ 495.) THE principal character of the salts of potash, as by the above table, is to give no precipitate, either by a hydrosulphuret or a soluble carbonate.

All the salts of potash are soluble; but there are some which are but slightly so.

When tartaric acid (which will be described when we come to treat of Vegetable Chemistry) is poured into a concentrated solution of any of these salts, a precipitation takes place, of a substance which is known by the name of *tartar*, of which we shall hereafter speak.

They also afford a precipitate when sulphate of alumine (§ 429.) is poured into them, on account of the formation of alum, which is a salt of sparing solubility.

Chloride of platinum (§ 395.) produces with them a yellow precipitate of a double chloride, which is nearly insoluble in water, and wholly so in alcohol.

Potash is the most powerful of all the bases, and forms the most permanent combinations with the acids. For example:—The nitric acid sustains a much higher heat without decomposition, when united with this base, than with any other; and the vegetable acids also have their decomposition much retarded by the same combination. In general it forms anhydrous salts.

Salts of Soda.

(§ 496.) THERE is a considerable analogy between the two bases, potash and soda. The salts of the latter, like those of the former, are very soluble; but they do not afford precipitates, as above described, with tartaric acid, sulphate of alumine, or chloride of platinum. If these tests should be insufficient to distinguish them in any case, the base should be separated and combined with sulphuric acid. The sulphate of potash is anhydrous, decrepitates in the fire,

is unaltered by exposure to the air, and of a bitter taste. The sulphate of soda, on the contrary, undergoes the aqueous fusion from the great quantity of water which it contains; effloresces in the air, and has a bitter, cooling taste.

Salts of Ammonia.

(§ 497.) THE general characters of the ammoniacal salts have been already enumerated (§ 187.). We will only add that, like potash, they afford precipitates with sulphate of alumine, and with chloride of platinum.

Salts of Lithia.

(§ 498.) THE salts of lithia are the first of the groupe which are precipitated by the carbonated alkalies; but, nevertheless, its carbonate is slightly soluble. This base may further be distinguished from potash and soda, by combining it with muriatic acid; its choride being very deliquescent and dissolving freely in alcohol, which afterwards burns with a red flame. All the salts, when heated on a platinum wire before the blowpipe, tinge the flame with a red colour. It is distinguished from the alkaline earths by forming soluble salts with sulphuric and oxalic acids, and by its carbonate, though sparingly soluble, giving a brown stain to turmeric paper.

Salts of Baryta.

(§ 499.) SOME of the salts of baryta are soluble, and some insoluble; but it is easy to change the latter into the former by converting them into a chloride.

The soluble salts are precipitated by sulphuric acid, and the precipitate is insoluble in excess of the acid: they are precipitated by caustic potash and soda, but not by ammonia. When a drop of a solution of the chloride is placed upon a slip of glass and exposed to the air, it crystallizes in distinct rhomboidal or hexahedral plates. These crystals are insoluble in alcohol, and do not undergo any change by exposure to the air. Their taste is peculiarly bitter, and they are violently poisonous.

Salts of Strontia.

(§ 500.) THE salts of strontia very much resemble those of baryta in their general characters, and it is sometimes difficult to distinguish them. Sulphuric acid produces, with both, a precipitate insoluble in excess. But the sulphate of baryta is absolutely insoluble in water; and if water, which has been boiled with it, be filtered and evaporated to dryness, there will be no residue. If, however, to water which has been boiled with sulphate of strontia, a few drops of any soluble salt of baryta be added, there will be a cloudiness produced, as the sulphate of strontia is very slightly soluble.

A drop of chloride of strontium, evaporated upon a slip of glass, crystallizes in slender prisms, which deliquesce in a moist atmosphere, and are soluble in alcohol. This salt is not poisonous.

Lastly, neither the solution of baryta nor strontia produces any precipitate with the salts of this base.

Salts of Lime.

(§ 501.) THE salts of lime are not precipitated by dilute sulphuric acid; but if the solutions be very concentrated, a precipitate will be produced. This precipitate, even, may be re-dissolved by the addition of nitric acid, which will not take up those formed by baryta and strontia. Solutions of baryta and strontia in water occasion precipitates in them. They are also precipitated by the oxalic acid (hereafter to be described), which has so great an affinity for the base, as to separate it even from the mineral acids. None of them are precipitated by ammonia. They have, in general, a pungent bitter taste

Salts of Magnesia.

(§ 502.) THE salts of magnesia are precipitated by solutions of all the caustic alkalies and alkaline earths. Ammonia, however, will not occasion any precipitate, if the salt contain more than one equivalent of acid; as in that case a double salt of ammonia and magnesia is formed, which a further addition of ammonia does not decompose. Ammonia, moreover, only precipitates half the magnesia of the neutral salts, and with the remainder forms a double salt. The salts of magnesia are precipitated by the neutral carbonates, but not by the bi-carbonates; for the bi-carbonate of magnesia, which is formed, is very soluble; but upon the application of heat, carbonic acid is given off and a precipitate ensues. They are not, like the salts of lime, precipitated by oxalate of ammonia, if moderately diluted, and the sulphate is very soluble in water, which distinguishes it from those of baryta and strontia.

The whole class possesses a peculiar bitter taste, which is also characteristic.

Salts of Alumine.

(§ 603.) THE salts of alumine are the first of the class which are precipitated

by a neutral hydro-sulphuret. They all change vegetable blue colours to red, and the base appears not perfectly to neutralize the acids. They possess a well-known sour astringent taste. If, into a solution of any salt of alumine, a salt of potash or ammonia be dropped, an alum is formed which is but little soluble. All the preceding bases precipitate alumine from its salts, but the precipitate is redissolved by an excess of alkali. When heated to redness with a few drops of solution of cobalt, they afford a beautiful blue colour.

Salts of Manganese.

(§ 504.) The salts of the protoxide of manganese are in general white, with a slight tint of rose colour. They are precipitated white by the alkalies; but the precipitates very speedily change to brown by absorption of oxygen. Ammonia, as in the case of magnesia, only precipitates half the base. Ferro-cyanate of potash (§ 490) also throws down a white precipitate. The salts of manganese may likewise be readily distinguished by their formation of *mineral chameleon* (§ 311.). If a small portion be heated with access of air in a crucible with potash, a mass is obtained which affords a green solution, which changes to red by the addition of a little acid.

Salts of Zinc.

(§ 505.) The salts of zinc are all white, if we except those formed by the chromic acid. They are precipitated white by the alkalies and by ferro-cyanate of potash. An infusion of *nut-galls* occasions no change in them. All the precipitates are soluble in excess of alkali, and especially in ammonia.

Salts of Iron.

(§ 506.) The salts of iron are easily recognized.

The salts of the protoxide are generally of a green colour, and possess an astringent taste. The alkalies precipitate them white, but the precipitate changes first to a green, and gradually to an ochreous colour: it is slightly soluble in ammonia. The ferro-cyanate of potash occasions a white precipitate, which, however, is more or less tinted with blue, if there be any particles present with excess of oxygen. Infusion of nut-galls does not occasion any precipitate with them. By exposure to air they become changed into sub-salts and acid-salts more or less coloured, which do not crystallize.

The salts of the per-oxide are precipitated of an intense blue colour by ferro-cyanate of potash. Infusion of nut-galls occasions a deep bluish-black precipitate, which is the basis of common writing ink. The alkalies precipitate them of an ochre colour.

Sulphuretted hydrogen does not precipitate the base of these salts, but reduces them to the state of proto-salts with an abundant precipitate of sulphur.

Salts of Cobalt.

(§ 507.) The salts of cobalt are of a rose or blue colour. The alkalies occasion with them a blue precipitate, which is redissolved by excess of ammonia. When melted with glass or borax they occasion a deep blue permanent colour. Ferro-cyanate of potash forms with them a deposit of a yellowish-brown colour.

Salts of Nickel.

(§ 508.) The salts of nickel are of a bright emerald green colour, which is easily distinguished from the dull green of other salts, as those of iron. The alkalies throw down a green precipitate, which becomes black by drying: it is soluble in an excess of ammonia, which forms with it a beautiful blue solution. The only two metallic oxides which afford blue solutions with ammonia are those of nickel and copper; and as the latter is easily distinguished by other tests, this property becomes distinctive of the salts of the former. Ferro-cyanate of potash forms a bright yellow precipitate.

The taste of these salts is sweet and metallic.

Salts of Chrome.

(§ 509.) We have seen that the protoxide of chrome forms a salifiable base (§272.), as the peroxide does an acid. The salts of the latter have been described as a class (§ 472); those of the former are of a beautiful deep green colonr. The alkalies throw them down of a greenish-grey colour; ferro-cyanate of potash of a green colour. Infusion of nut galls occasions a brown precipitate. When any salt of the base of chrome is treated with nitre at a red heat, chromate of potash is produced, which, as we have seen (§ 473.), is of a yellow colour, and half a thousandth part of which, in water, is clearly perceptible. The oxide of chrome, which is thrown down by the

alkalies, is easily recognized by the green colour which it communicates to glass at a high temperature.

Salts of Tin.

(§ 510.) The preceding groupe of salts are precipitated by hydro-sulphuret of ammonia; but not by excess of sulphuretted hydrogen; the following division consists of those which are thrown down by sulphuretted hydrogen alone. There are two series of the salts of tin: those of the protoxide and those of the peroxide.

The proto-salts afford a brown precipitate with sulphuretted hydrogen. Potash and the other alkalies occasion a white deposit, which retains a small quantity of chlorine, when the salt is a muriate: with an excess of alkali and heat, the black oxide is obtained, which is easily reduced with a little charcoal, and the metallic button may be recognized by the peculiar smell of tin when rubbed. Ferro-cyanate of potash throws down a white precipitate. Tin is the first of a series of metals which may be precipitated by other metals which have a superior attraction for oxygen. If a small plate of zinc be immersed in a solution of tin, a grey deposit will immediately take place upon it: this will be succeeded by brilliant metallic scales which strongly reflect the light. The tin is precipitated, and the zinc takes its place with the solvent: not a particle of the former will remain in solution. Although this effect is primarily occasioned by the greater affinity of zinc for oxygen, another cause contributes to it; the coat of tin which is first precipitated upon the zinc forms with it a galvanic arrangement, and the decomposition proceeds from the electric action which is excited. A kind of metallic vegetation takes place in the solution, and the distant effect at the extremes of the branches cannot be supposed to be the result of chemical affinity.

The proto-salts of tin have the property of precipitating chloride of gold of a purple colour, as we have already seen (§ 393).

The per-salts of tin are distinguished from the preceding by affording a dingy yellow precipitate with sulphuretted hydrogen, which is analogous to the mosaic gold before described (§ 289.). They are easily reduced to salts of the protoxide, by adding metallic tin to their solutions. They are not precipitated by mixture with water.

Salts of Cadmium.

(§ 511.) The salts of cadmium are precipitated by the alkalies in the state of a white hydrate, which is redissolved by an excess of ammonia. The precipitate from sulphuretted hydrogen is of an orange colour, and is insoluble in pure potash, and sustains a white heat without subliming. Cadmium is thrown down in the metallic state from its solutions by metallic zinc. The oxide is readily reduced by mixture with charcoal, and the metal immediately recognized by its great volatility.

Salts of Antimony.

(§ 512.) The salts of base of antimony possess the remarkable property of being precipitated by water. If we take the chloride, for example, we shall thus obtain liquid muriatic acid, containing a little antimony in solution, and the precipitate will consist of a sub-salt. By treating it with excess of alkali, the oxide is obtained in a state of purity. Antimony, like tin, is precipitated in the metallic state by zinc. It is also reduced by tin; and this is a convenient way of separating the two metals when mixed. By immersing a plate of tin into a solution of the two metals all the antimony will be precipitated. The salts of antimony are not precipitated by ferro-cyanate of potash; and, as there are but two or three others which escape the reaction of this salt, the character is important. The precipitates of antimony are easily reduced with charcoal, and the metal recognized without difficulty.

Salts of Bismuth.

(§ 513.) The salts of bismuth are colourless, and yield an intensely black precipitate, with sulpuretted hydrogen. Tin, copper, and zinc precipitate the metal from their solutions. It may be recognized by its reddish-white colour, and by its great brittleness.

The nitrate of bismuth affords, with water, a copious white precipitate, and the metal may by this means be both distinguished and separated from others. It consists of a sub-nitrate, which, on account of its great beauty, has been employed as a paint for improving the complexion.

Salts of Lead.

(§ 514.) The salts of lead are all white, with the exception of those which are formed with the coloured metallic acids.

The alkalies precipitate from them a white hydrated oxide; and sulphuretted hydrogen throws them down of a black colour. The sensibility of the latter test is so great, that it will detect the hundred-thousandth part of the metal in any solution. Lead is one of the few metals which form an insoluble salt with sulphuric acid; and if the solution of any sulphate be dropped into the solution of any of its salts, a copious white deposit will be produced. It is, however, soluble in an excess of sulphuric acid.

Ferro-cyanate of potash produces a white precipitate. They are reduced to the metallic state by zinc, tin, and many other metals. We have already described a precipitation of this nature as an illustration of chemical affinity (§ 26.).

The salts of lead have a peculiar sweet astringent taste, very different from the metallic flavour of those of other metals.

Salts of Copper.

(§ 515.) THE solutions of all the salts of copper have a blue colour when diluted, and green when concentrated. This alone is sufficient to distinguish them from those of any other metal.

A small proportion of potash precipitates, from the sulphate, a green subsalt; but in excess it throws down the black oxide. Ammonia redissolves the precipitate, and a splendid deep blue solution is produced.

Ferro-cyanate of potash causes a red or copper-coloured precipitate, which is quite characteristic of the metal. The copper is deposited in the metallic state both upon zinc and iron. The taste of the salts of copper is styptic, and highly nauseous, and they are all poisonous.

Salts of Mercury.

(§ 516.) THE salts of both the protoxide and the peroxide of mercury are decomposed or volatilized by the action of heat; the chorides sublime; the nitrates are decomposed with the production of oxygen and metallic mercury. They are precipitated by the alkalies, and the precipitate gives off oxygen when heated. The black deposit which is formed by sulphuretted hydrogen changes to the colour of cinnabar when reduced to an impalpable powder. The precipitate from the proto-salts by the alkalies is black; that from the per-salts yellow.

Ferro-cyanate of potash produces a white precipitate with this class of salts.

Salts of Silver.

(§ 517.) THE solutions of the salts of silver are colourless; alkalies throw down from them a black precipitate, which is reduced to the metallic state upon red-hot charcoal. Silver, lead and mercury in the lowest state of oxidation are the three metals which form insoluble salts with sulphuric acid; a small quantity of the first, however, is taken up.

The salts of silver are precipitated by the chlorides, and the deposit, when exposed to light, changes from white to a deep violet colour. It is soluble in ammonia; but wholly insoluble in water or acids. This chloride of silver is reduced to the metallic state by the greatest part of the other metals. Silver may be reduced from its combination with nitric acid by copper and by mercury.

Salts of Platinum.

(§ 518.) THE solutions of platinum (§ 395.), which are of a yellow colour, are not precipitated by ferro-cyanate of potash; and this is a very distinctive character. Muriate of potash and muriate of ammonia both throw it down of a yellow colour, in the state of a double salt. This metal, having a very slight affinity for oxygen, is precipitated by many others, and even by silver.

Salts of Gold.

(§ 519.) THE solutions of gold are also of a yellow colour. The gold is precipitated from them in the metallic state by proto-muriate of iron, and, as we have just seen (§ 511), as a purple powder by proto-muriate of tin.

(§ 520.) Such are the characters by which the bases of the principal salts may be distinguished; and which, with the leading characters derived from their acids, and the properties of the individual species which we have before described, afford us the ready means, by simple and well-directed experiments, of recognising any unknown specimen. For facilitating such examination, every practical chemist provides himself with solutions of the three mineral acids, the alkalies, and the alkaline carbonates of absolute purity and of definite strength, so calculated that one measure of the one will either neutralize one measure, or some simple multiple of one, of the other. He also is careful that the solutions of such salts as he may employ for re-acting upon the elements of other salts of unknown constitution are in a

state of purity; and such solutions he distinguishes by the name of *tests* or *re-agents*. The apparatus in which all the solutions, digestions, evaporations and precipitations necessary for these purposes are effected is of the simplest nature; and consists of thin tubes closed at one end, and called *test tubes*, watch glasses, and small plates of glass, and glass rods: and it should be well impressed upon the mind of the student, that one of the most useful of experimental acquirements is a facility of effectually substituting an apparatus or vessel at hand for another that is wanting. The smallest quantity of a re-agent may be added to a drop of a solution placed on a glass plate, and from its transparency, and the different positions in which it may be held, the appearances and changes may be viewed to the greatest advantage. The forms of any crystals may also be very satisfactorily determined by the slow evaporation of a small drop of their solution upon a similar plate. The facility, the neatness and precision with which one who is well acquainted with the resources of his art, will often proceed to determine the nature of an unknown body by the microscopical changes which take place in drops of different solutions upon a slip of glass, would appear little less than miraculous to a person who was unacquainted with the definite nature of chemical compounds; but nothing but deep study and persevering practice can render a chemist master of these elegant processes for detecting minute portions of matter. It is impossible that we should, upon the present occasion, enter upon the minutiæ of chemical manipulation; and as this treatise is only designed as an introduction to a complete body of chemistry, or as a kind of skeleton to denote the connexion of the different parts, we must refer to future essays for the details which will be necessary to those who wish to become proficients in this useful and fascinating science.

We shall now recapitulate the composition of the principal salts before described in the form of a table.

TABLE VII.

Salts or Compounds of the Acids and Bases.

		Equivalents			
Nitric Acid (1 N 14 + 5 O 40)	Nitrate of Potash	102	1 N 54	+	1 P 48
	Soda	86	1 N 54	+	1 S 32
	Ammonia	71 + 9 W	1 N 54	+	1A17+1W9
	Baryta	132	1 N 54	+	1 B 78
	Lime	82	1 N 54	+	1 L 28
	Copper	188	2 N 108	+	1 C 80
	Lead	166	1 N 54	+	1 L 112
	Protonitrate of Mercury	262	1 N 54	+	1 M 208
	Pernitrate of ditto	486	1 N 54	+	2 M 432
	Nitrate of Silver	172	1 N 54	+	S 118
Chloric Acid (1C 36 + 5 O 40	Chlorate of Potash	124	1 C 76	+	1 P 48
	Soda	108	1 C 76	+	1 S 32
	Baryta	154	1 C 76	+	1 B 78
Perchloric Acid (1 C 36 + 8 O 64)	Perchlorate of Potash	148	1 P C 100	+	1 P 48
Muriatic Acid (1 C 36 + 1 H 1)	Chloride of Potassium	76	1 C 36	+	1 P 40
	Sodium	60	1 C 36	+	1 S 24
	Muriate of Ammonia	54 + 9 W	1 M 37	+	1A17+1W9
	Chloride of Barium	106	1 C 36	+	1 B 70
	Calcium	56	1 C 36	+	1 Ca 20
	Protochloride of Copper	100	1 C 36	+	1 Co 64
	Perchloride of ditto	136	2 C 72	+	1 Co 64
	Chloride of Lead	140	1 C 36	+	1 L 104
	Protochloride of Mercury	236	1 C 36	+	1 M 200
	Perchloride of ditto	272	2 C 72	+	1 M 200
	Chloride of Silver	146	1 C 36	+	1 S 110
Iodic Acid (1 I 124 + 5 O 40,	Iodate of Potash	212	1 I 164	+	1 P 48
Hydriodic Acid (1 I 124 + 1 H 1	Hydriodate of Potash	173	1 H 125	+	1 P 48
	Ammonia	142	1 H 125	+	1 A 17

		Equivalents			
	Sulphate of Potash	88	1 S 40	+	1 P 48
	Bisulphate of ditto	128	2 S 80	+	1 P 48
	Sulphate of Soda	72	1 S 40	+	1 So 32
	Ammonia	66	1 S 40	+	1 A 17 + 1 W 9
	Baryta	118	1 S 40	+	1 B 78
	Lime	68 + 18 W	1 S 40	+	1 L 28 + 2 W 18
Sulphuric Acid	Magnesia	60	1 S 40	+	1 M 20
(1 S 16 + 3 O 24)	Alumine	58	1 S 40	+	1 A 18
	Protosulphate of Iron	76	1 S 40	+	1 I 36
	Persulphate of ditto	100	1½ S 60	+	1 I 40
	Sulphate of Copper	160 + 90 W	2 S 80	+	1 C 80 + 10 W 90
	Protosulphate of Mercury	248	1 S 40	+	1 M 208
	Persulphate of ditto	296	2 S 80	+	1 M 216
	Sulphate of Silver	158	1 S 40	+	1 Si 118
Sulphuretted Hydrogen (1 S 16 + 1 H 1)	Hydrosulphuret of Potash	65	1 H 17	+	1 P 48
	Ammonia	34	1 H 17	+	1 A 17
Phosphoric Acid (1 P 12 + 2 O 16)	Phosphate of Soda	60	1 P 28	+	1 S 32
	Lead	140	1 P 28	+	1 L 112
	Carbonate of Potash	70	1 C 22	+	1 P 48
	Bicarbonate of ditto	92	2 C 44	+	1 P 48
	Sesquicarbonate of ditto	81	1½ C 33	+	1 P 48
	Carbonet of Soda	54	1 C 22	+	1 S 32
	Bicarbonate of ditto	76	2 C 44	+	1 S 32
	Sesquicarbonate of ditto	65	1 C 33	+	1 S 32
Carbonic Acid	Carbonate of Ammonia	39	1 C 22	+	1 A 17
(1 C 6 + 2 O 16)	Bicarbonate of ditto	61 + 18 W	2 C 44	+	1 A 17 + 2 W 18
	Sesquicarbonate of ditto	50 + 9 W	1½ C 33	+	1 A 17 + 1 W 9
	Carbonate of Baryta	100	1 C 22	+	1 B 78
	Lime	50	1 C 22	+	1 L 28
	Magnesia	42	1 C 22	+	1 M 20
	Iron	58	1 C 22	+	1 I 36
	Copper	102 + 9 W	1 C 22	+	1 C 80 + 1 W 9
	Lead	134	1 C 22	+	1 L 112
Boracic Acid (1 B + 2 O 16)	Borate of Soda	76	2 B 44	+	1 S 32
Chromic Acid (1 C 28 + 3 O 24)	Chromate of Potash	100	1 C 52	+	1 P 48
	Bichromate of ditto	152	2 C 104	+	1 P 48
Hydrofluoric Acid (1 F 18 + 1 H 1)	Hydro-fluate of Ammonia	36	1 H 19	+	1 A 17
	Fluoride of Calcium	38	1 F 18	+	1 C 20

(§ 521.) The very confined limits imposed upon us oblige us here to terminate this condensed account of the *Chemistry of Inorganic Substances.* The student who shall have attentively followed us thus far will, it is hoped, have formed such an acquaintance with those forms of matter which the present state of our knowledge obliges us to consider as elementary (or *ultimate principles*), and of the simple laws by which they combine and form compounds capable of further definite combination (and which may be designated as *proximate principles*), as well as of the still simple products of these latter, in which all chemical affinities seem to be saturated, as may enable him to understand the more complicated and obscure products of the organic creation.

In the inorganic department of Nature which we have hitherto discussed, the ultimate principles are numerous: but they generally unite in binary combinations, and by the direct union of such binary combinations others are finally produced. In the products of the organic department, upon which we are next to enter, under the mysterious agency of vegetable and animal life, the ultimate principles are far less varied; but there is much more diversity in the modes in which they are combined. The elementary substances and the laws of affinity are the same in both; but instead of the mere binary combinations of the mineral kingdom, the vegetable and animal kingdoms present us with individual compounds in which the affinities of three, four, or more substances are balanced in complicated states of union. It is this comparative simplicity

of construction which confers upon the various compounds which we have been considering a permanancy, under ordinary circumstances, which is commonly wanting in the classes which remain for description: they are in general little liable to spontaneous changes, and the balance of their affinities is not easily subverted. The relative force of attraction by which their principles are united can, in some measure, be estimated, and the circumstances by which that attraction is modified determined; so that by presenting these principles to each other under these circumstances we can effect their combination, or form compounds of precisely the same properties. We can analyse these compounds with equal facility, or by a simple decomposition separate their principles so as to obtain them isolated. Their composition can, therefore, be ascertained with accuracy, and not only the nature and proportions of their constituent parts, but the modes in which these are combined.

The chemical characters of vegetable and animal products are, as we shall hereafter see, altogether different. As they always consist of three or more principles which have strong mutual attractions, the balance, by which any particular compound exists, is easily disturbed; the principles have a perpetual tendency to react on each other, and form new combinations, and the slightest alteration of circumstances gives efficiency to this tendency. Hence they are liable to spontaneous changes from alterations of temperature; and water, which, in the class which we have been considering, under ordinary circumstances, only exerts that minor degree of chemical affinity by which solution is effected (§ 12), becomes with them, under similar circumstances, decomposed, and introduces new elements of change.

From our ignorance of all the necessary conditions of the problem, we are also unable artificially to balance the attractions of the principles of which organic bodies are formed, or to place them under the circumstances under which they were brought into union in the vessels of the animal or plant; and can seldom, therefore, form compounds of a similar nature.

Another cause of the grand distinction which exists between the chemistry of inorganic and organic substances may be found in the nature of those elements which constitute the basis of the latter; these are oxygen, hydrogen, nitrogen, and carbon: the three first are permanently elastic fluids, and incapable of assuming the liquid form by any means at present known to us, and are also nearly insoluble in every liquid: the second is as permanent a solid, incapable of fusion, and insoluble in any known menstruum; consequently the elasticity of the former and the cohesion of the latter present obstacles to their combination, which the force of affinity is incapable of overcoming. (§ 3.) The action of a high temperature alone, under such circumstances, could give efficiency to the latter; but such a temperature is inconsistent with the existence of any organised body.

(§ 522.) An analogous instance, however, presents itself to us in the mineral kingdom in the class of silicious compounds, respecting which there exists more uncertainty than with regard to any other products of inorganic chemistry. We are unable to imitate the various combinations of silex with other oxides which are presented to us in nature; and although the art of analysis can reduce them to their elements, and assures us of their definite composition, the infusibility and insolubility of their principal ingredient renders it impossible, in most cases, to bring into play the affinities which would doubtless be developed, if the strong opposing power of cohesion could only be overcome. We are thus deprived of that higher degree of certainty with regard to the constitution of these bodies, which forms the perfection of chemical demonstration (§ 47.). It is on this account that we refer, as we have before stated (§ 186.), to the Treatise on Mineral Analysis for an account of those peculiar natural products of the mineral kingdom.

(§ 523.) We are not, however, to suppose that the two great branches of the science, *inorganic* and *organic* chemistry are totally separated from one another by the marked line of distinction which we have been pointing out: there are no such defective links in the great chain of natural knowledge. The division is artificial; and, like other instances of classification, insisted on as a help to memory. The two divisions amalgamate, as we shall find, at various points in the order of nature: and not the least interesting part of our future researches will be into the action of mineral upon vegetable and animal products, and the various combinations of inorganic with organic principles; which are the real creations of art working with the powers of nature.

BOTANY.

Botany is that branch of natural history which relates to the structure, vital action, classification, and uses of those objects in the organic world which we call plants. In the language of some persons, indeed, it is confined to a mere explanation of the art of classifying plants, and to the power of using such classifications so as to ascertain the name of a given species with certainty; by others it is allowed to comprehend a knowledge of the various kinds of structure which we meet with in the vegetable kingdom, but scarcely to extend beyond those two departments. But, in reality, the former of these objects, however important, is only a collateral branch of the subject; and the latter is but a portion, although an essential one, of those investigations from which botany derives its claim to the rank of science.

The study of the works of nature, independently of its contributing in a powerful degree to elevate the mind of man, and to bring him into communion with his Creator, is of great consequence, as being the means by which he is enabled to compel all living things to minister to his comforts, his pleasures, or his necessities. It is to the latter objects, chiefly, that naturalists usually direct their attention; because it is justly supposed that all higher considerations of necessity grow out of the investigations in which we must engage, in order to apply any branch of natural history to practical purposes.

The properties of vegetable productions, with reference to their utility to mankind, are influenced by the species or varieties from which they are derived; by the mechanical structure or chemical composition of the part of the plant made use of; and by the phenomena and changes connected with the action of the vital principle of vegetation, which may be considered either independently of external circumstances, or when controlled either by natural causes or by artificial means. In order to apply the knowledge of such objects usefully, and to render it available to others, arrangement and method are indispensable; not only in regard to the ideas derived from a consideration of the nature of plants, but in regard to plants themselves.

Hence four grand divisions of the science of botany into—

I. Structural Botany; which comprehends whatever relates to the laws of vegetable structure, whether external or internal, independently of the presence of a vital principle.

II. Physiological Botany; to which belongs all that concerns the history of vegetable life, from the moment when the vital principle is imparted to the seed and the plant first breaks its shell, to the period of death: explaining the functions which the various organs are destined to perform; the changes they undergo in health or sickness, and under all the influences exercised by climate, seasons, accidents, or the art of man.

III. Descriptive Botany; from which we learn the art of describing plants with accuracy, so that their characters may be recognized with certainty by others, and of giving to plants names by which they can be mentioned without confusion when written or spoken of.

IV. Systematic Botany; which explains the principles upon which are determined the mutual relations that combine the seemingly discordant members of the vegetable kingdom into one harmonious whole; and which teaches the art of distinguishing any plant from all others, so as always to determine its name with precision.

These subjects we shall treat in the order in which they have been mentioned.

Part I.—Structural Botany.

Chapter I.

A general view of the external Structure of a Plant complete in all its Parts.

A plant is a living body, deprived of sensation or power of moving from place to place, and fed by means of external roots.

Animals, on the contrary, are endowed with sensation and the power of voluntary motion from place to place; and are fed by means of an internal bag consisting of one or more stomachs.

These differences are readily enough observed between animals and plants of the higher and more perfect grades; but there are many of the more minute, and apparently more simple, kinds which it may appear difficult to refer with certainty to either of the above classes. Aquatic animals of the polypiferous kind, for instance, have not only very much the appearance of a plant, being attached to rocks by a sort of root; but actually grow, as plants do, by the continual emission of new branches. Marine plants, like these animals, derive no food from their apparent root, and seem to have a sort of universal external stomach; while some of the minuter kinds of filamentous aquatic plants or sea-weeds, after being detached from the soil by accident or otherwise, continue to grow as they float in the water, and often appear to have a certain degree of motion, when it may be difficult to ascertain with certainty whether it be owing to internal volition or to external physical influences. In these cases the mode of nutrition is the only certain test by which the objects in question can be referred to one of the great kingdoms of animals and plants.

It is, however, obvious, that whatever difficulties may attend the distinguishing of plants from animals in particular cases, their differences are, generally, sufficiently apparent. Without occupying ourselves, then, with a question which belongs to the theory of creation more than to botany, let us cast a hasty glance over the structure of some plant in which is present every organ that is usually met with in what we consider a species complete in all its parts.

Such a plant is the violet (Viola odorata), or the heart's-ease (Viola tricolor). The latter consists of a number of green, or yellow, or purple parts, arranged symmetrically upon a green angular axis, which puts forth under ground many slender whitish threads, divided in an irregular manner. The green angular axis (*fig.* 1, *a*) is the *stem*, the slender threads (*b*) are *roots.*

Upon the stem are placed, at equal distances, certain flat, green, toothed bodies, which gradually taper into a thin stalk; it is almost superfluous to say that these are *leaves* (*c*). At the

Fig. 1.

base of each leaf are placed two other thin green parts (*d*), which are very like the leaves, only they are smaller, and are deeply gashed near the bottom instead of tapering into a stalk; to these is given the name of *stipules.*

The axis, consisting of stem and root, together with the leaves and stipules, forms the *organs of vegetation;* so named because they have no other destination than to enable a plant to

live and grow, and perform those vital actions which are not connected with the office of spontaneous propagation.

From the angle (*e*), formed by the junction of the leaf with the stem, which is called the *axil*, springs a slender angular stalk, on the top of which the flower is seated. This stalk, called the *peduncle*, has, near its upper end, a couple of little scales (*f*) named *bracts*, which are of a nature intermediate between the organs of vegetation and those of *fructification*. The latter name is given to the parts of a flower, because their office is exclusively to enable a plant, by fructifying, to multiply its species spontaneously.

The *flower* consists, externally, of five small, narrow, green leaves (*g*), called *sepals*, and of the same number of larger yellow and purple leaves (*h*), called *petals:* the sepals taken collectively form a *calyx*, and the petals, in like manner, form a *corolla*. These two are often named *floral envelopes*.

Within the petals, and quite hidden from view by the bases of those organs, until they are pulled off, is a row of five thin, pale-yellow parts (*i*) sticking together a little by their edges, but separated from the body they surround; they are named *stamens*, and are the fertilizing apparatus of the flower. They surround a hollow body (*k*) tapering into a zigzag cone, and terminating in a globular head: this is the fructifying apparatus, and is called the *pistil;* within its hollow base may be found the young seeds, which we name *ovules*, from their resemblance to little eggs, or *ova*.

By certain curious operations, which need not now be explained, the pistil is fertilized; after which it swells, alters its form and texture, and at last becomes the *fruit* (*l*), which is hard and dry, splits into three pieces, and sheds the seeds which, by that time are ripe and fully formed. The seed (*m*) consists of a shell, containing a quantity of fleshy matter (*o*), from its resemblance, in use, to the white of an egg, called *albumen;* in the midst of which lies an *embryo* plant (*n*), which is supposed to be nourished by the albumen until it breaks the shell and is strong enough to gain its food for itself.

Such is the heart's-ease; such are the organs which constitute the fabric of all the most perfectly constructed plants. Lowly a species as it is, it comprehends every part that is employed by nature in the formation of the loftiest tree of the forest; the difference in size between it and a tree being caused by nothing more than an endless multiplication of similar parts of vegetation, constructed always upon a similar plan, adjusted to each other in the most admirable manner, and all working in perfect harmony and order. The stem in the heart's-ease perishes every year; in an oak it lives from year to year and from age to age, constantly augmenting in size. This, however, is not owing to any material difference in the structure of the two species, but to a specific power of prolonged vitality in trees, which plants like the heart's-ease are destitute of. To make this more intelligible, suppose a heart's-ease to produce, in the course of the first year of its life, a stem with twenty leaves, and that its stem is hard and perennial, instead of soft and annual. In the second year, its stem, by virtue of a power hereafter to be explained, may form a new branch at the axil of each of its twenty leaves; and as the second branches may be as large, at least, as the first, it may, therefore, multiply its dimensions twenty times. In the third year the same operation may take place; and the consequence of this will be, an augmentation equal to four hundred times its original dimensions; and so on in a geometrical ratio. At this rate a heart's-ease would soon develop into an enormous tree; and although that species never does so change its nature, yet it is quite true that every tree, in the first year of its existence, is formed upon a plan analogous to that of the heart's-ease, and never more complicated; and that its subsequent growth into a giant of the forest takes place upon the plan that has just been adverted to in a suppositious case.

The adaptation of all these parts to the maintenance of a perfect system of life, in which each organ performs its allotted office with unvarying regularity and with the most admirable harmony, so that no one interferes with another, is among the most beautiful instances of contrivance in the creation. It is the especial business of physiological botany to explain this, which will therefore be the subject of detailed illustration hereafter. In the meanwhile, a brief exposition of the

leading functions of the several organs will render the account we shall have to give of their structure more interesting to the general reader than it otherwise would be.

The root is the part which attracts the liquid food of plants from the soil in which it is mingled, and impels it upwards into the woody part of the stem. Once introduced into the system of a plant, this food becomes altered from what it originally was, and is called *sap.*

Sap rises through the woody part of the stem, dissolving what soluble matter it meets in its passage, and at last is impelled into the leaves. Having arrived in those organs, it loses water by evaporation; peculiar chemical changes are produced in it by exposure to solar light; and at last, having been converted into the secretions peculiar to the species in which it is formed, it is returned from the leaves back into the stem, down which it descends, through the *cortical layer* or bark, passing off laterally into the centre of the woody matter in its downward course. In the bark and the centre of the stem a considerable proportion of the peculiar secretions from the sap is finally stored up, and eventually all those substances which it is necessary that the plant should get rid of are passed off into the earth again by the roots. Thus an ascending current of crude sap, a descending flow of elaborated sap, and a lateral deposit of the latter in the stem, are going on during all the time that a plant is in a growing state; and, in consequence of special routes being assigned to each of these currents, they act without in the slightest degree interfering with each other. By what particular vessels and by what microscopic apparatus this vegetable laboratory is kept in action, will be fully explained hereafter.

In the flowers the calyx and the petals may be supposed to act to a certain extent as leaves, to furnish food for the stamens and the pistil, which are enclosed within them. The stamens and pistil continue to increase with equal steps up to a certain period, which is the maturity of the former, and the commencement of a new growth in the latter. At this time the upper part of the stamen bursts and discharges a fine powder, the motes from which fall upon the tip of the pistil, which, at that particular time, becomes viscid, for the purpose of causing the motes to adhere to it. Here the motes, which in reality are hollow globes, filled with fertilizing matter, absorb the circumambient moisture, distend, and at last discharge upon the humid point of the pistil that matter whose mysterious influence is to cause the pistil to fructify. This accomplished, the stamens wither and die; but the pistil, to which a new life has been thus imparted, goes on growing and swelling; the ovules distend, and occupy all the cavity of the pistil; in their inside a little being is born, which feeds upon the liquid albumen, and at last assumes the form of a microscopic plant. When this takes place, the parts of the pistil lose their green colour, and assume the livery of death; the integuments of the ovule harden, seeds are formed, and in order to enable them to escape from the prison in which they are locked up within their parent fruit, the sides of the latter give way, either by rending, or splitting, or decaying, and allow the seed to fall upon the earth. There it lies till the hour for its further progress is at hand, when the moisture in the soil becomes warmed by the rays of the sun; a stimulus is thus communicated to the embryo plant, which swells, lengthens, pushes forth a tiny root through an opening in its shell, and at last disengaging itself altogether from its hard integuments, unfolds its little leaves, rears its stem into the air, pushes its roots down into the soil, and thus establishes itself as a new individual, with power to bear all the organs, to undergo all the vicissitudes, and to accomplish the same destiny as the parent from which it sprang.

This may be considered a correct view of the course of many a vegetable life; no doubt, there are many modifications of all these phenomena, and even some exceptions to them, but with these we are not to occupy ourselves in the present place.

Chapter II.

Of the degree in which perfect external Structure is departed from.

Although all the parts just named concur in the formation of a plant of the most perfect kind, there is not one of them that, in one species or another, is not either altogether wanting, or so altered in its nature as scarcely to be recognised. The root itself, by

which the food is conveyed into the body, is searcely present in sueh marine plants as seaweeds, and even in the dodder (Cuscuta) whieh grows upon heaths, and the mistletoe, whieh fastens itself as a parasite upon other species, it is so rudimentary as to be scareely eapable of action.

The stem in numerous species is so short as to be almost invisible. Leaves are frequently mere seales which drop off almost as soon as they are formed, leaving the plant to shift for itself by the aid of other means, as is the case in cactuses, stapelias, and the like. Both leaf and stem are so blended into one body in the duekweed (Lemna) that it is difficult to say whether the part that really exists is the one or the other. Stipules are as often wanting as present. Braets, in like manner, are frequently missing. Of the floral envelopes, sometimes the corolla is absent, as in the mezereon; and sometimes both ealyx and eorolla, as in the willow.

Even the stamens and pistils themselves disappear in a large number of plants. It is, however, to be remarked that this latter cireumstanee is always attended with a corresponding imperfection in the whole of the other organs, and is, therefore, before all other things, considered an indication of a greater degree of general imperfeetion. Ferns, for instanee, in which this oeeurs, have neither ealyx nor corolla, nor is their stem like that of other plants; in mosses, moreover, the leaves are mere scales; in lichens, the whole plant consists of but a flat plate composed of leaf and stem combined, with nothing for their seeds but exeessively minute transparent bladders; and, finally, some confervæ and fungi are destitute at onee of every one of the usual organs, consisting of nothing but a cell or two of exceedingly small size, in whieh the essenee of root, stem, leaf, flower, and fruit, without the form, is supposed to be comprehended.

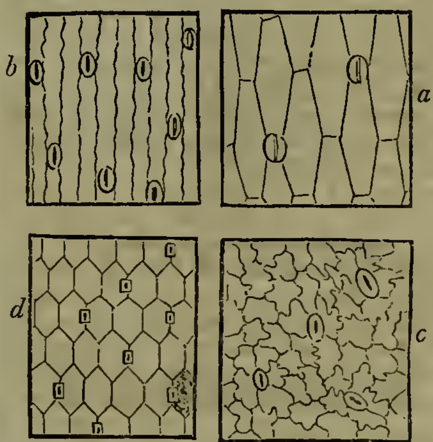
From these eauses the diversity of appearance in the vegetable kingdom is very great. But an examination of all the organs in detail will show that every speeies is in that state whieh is best adapted to the purpose for which it is destined: and that plants, from the extremely simple plan upon whieh even those whieh are apparently most eomplieated are organized, offer peeuliar faeilities for the transfer of the functions of one organ to another.

Chapter III.

Of the Skin of a Plant, and the Parts connected therewith. Stomates, Hairs, Glands, Stings, Scurf, Prickles.

Over every part of a plant exposed to the air, except the stigma, is extended a skin, which serves at onee to hold together and protect the parts beneath it. To the eye, even when assisted by powerful microscopes, it usually appears to be a thin transparent membrane, traversed by veins arranged with regularity in a netted manner. The meshes formed by the supposed veins are sometimes long hexagons (*fig.* 2, *a*); sometimes nearly regular

Fig. 2.



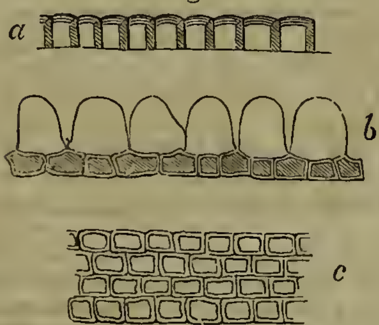
ones (2, *d*), resembling very mueh the panes of glass in some Gothic window; or they are some other figure more or less approaehing the hexagon. More uncommonly they have an exeeedingly wavy, eurled outline, as in the eommon polypody (Polypodium vulgare) (2, *c*); and oeeasionally they are bounded by undulated parallel lines, as in the white lily (Lilium eandidum) (2, *b*). In some instances the skin can be peeled off readily; in others, it adheres so firmly to the substanee beneath it, that it eannot be separated.

But if it is examined with greater eare and better glasses, it will be found to be by no means a simple membrane as it appeared at first sight. By making extremely thin sliees of any part of a leaf for instance, perpendieular to its surface, and plaeing them in water under a powerful mieroseope, we find that this apparent membrane is in reality an excessively thin plate,

formed by the growing together of a vast multitude of little bladders or cells, squeezed flat, filled with air, and joined by their edges, which are what give the appearance of veins to the skin when it is peeled off.

The thickness, the form, and the number of layers of these little bladders are variable in different species; being apparently diversified according to the different circumstances under which species are exposed to the action of the atmosphere. Thus, in the white lily, the German iris, and the common bean, and perhaps the greater part of European plants, the bladders are in a single layer, and very thin-sided (3, *a*); in some succulent plants they are in three rows, one of which sometimes has the sides of the outer layer of cells partially separated from each other, as has been remarked by Adolphe Brongniart in Rochea falcata (3, *b*), when the surface of the plant acquires a warty appearance; in the *oleander* there are three or four layers of thick-sided cells (3, *c*).

Fig. 3.



The object of these differences in the structure of the skin will be explained when the nature of the functions of that part comes to be considered. For the present it is sufficient to state that they are principally intended to adapt a plant to the nature of the medium in which the leaves are developed. It is a general rule that leaves growing in the air have a skin, and that those growing constantly in water have none; and it being necessary that evaporation should be regulated in the former case, while in the latter no evaporation can take place, it is inferred that this duty devolves upon the cuticle, which in fact is admirably adapted to the purpose. In plants growing in the shade, or in damp situations, the cuticle is thin and soft, and readily permeable to water in a gaseous state, but in leaves exposed to much heat and dryness it becomes proportionably thick and hard; in succulent plants in which evaporation is hindered, in order that their dropsical condition may be insured, more layers than one of cuticle are often present; and finally, in the oleander, which has to bear the parched atmosphere of a Barbary summer, there is a triple coating of hard thick cuticle.

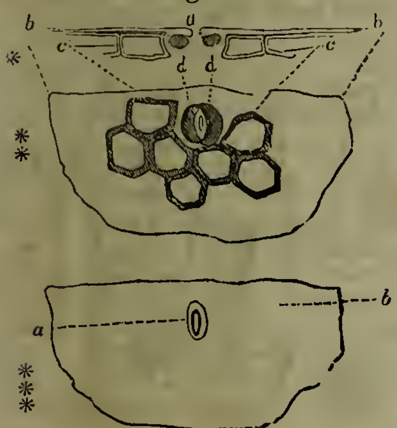
It appears probable, from the observations of Henslow and Adolphe Brongniart, that over the true skin is drawn an excessively thin pellicle which exhibits no appearance of organization, and which is perfectly homogeneous and continuous, except over the openings of the stomates. It is supposed that this pellicle, the use of which is unknown, may be what repels the water from the surface of some leaves, and causes it to separate into drops. It is difficult to detect it in the fresh leaf, in consequence not only of its being firmly glued to the subjacent cuticle, but also because of its thinness and transparency. It may be, however, easily detected, by macerating a leaf for a day or two in water, slightly impregnated with nitric acid, when it may be easily peeled off; for, notwithstanding its thinness, it is often remarkably tough.

Among the meshes of the skin may be remarked a number of oval spaces, much smaller than the meshes themselves, and placed upon the lines that indicate the juncture of the little bladders. These oval spaces (*fig.* 2) are the *stomates* above referred to of plants, and have a highly-curious structure. They are openings through the skin into the inside of a plant, and serve to establish a communication between the atmosphere and a complicated pneumatic apparatus which lies beneath the skin. They are constructed of two little oblong bladders, placed parallel with each other, and having a power of contraction or expansion, as circumstances may require: when at rest they are perfectly parallel, and, by pressing their sides together, close up the opening; when in action they curve away from each other in the middle, and thus leave the passage open.

The stomates sometimes seem bounded by a transparent limb, which is the portion of the pellicle between the blad-

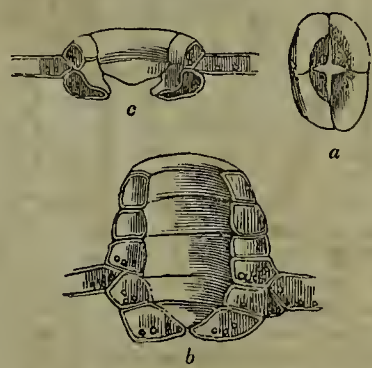
ders of the stomate and the contiguous bladders of the skin. When open they also appear as if two other little bladders interposed between the principal bladders and the opening; this is, however, a mere optical deception, caused by the thickness of the edge of the opening through the pellicle. The structure of these curious organs will be best understood from the following highly magnified figures. *Fig.* 4* represents a section of the skin of a plant perpendicular to the surface; *a* is the opening through the pellicle; *b* is the pellicle itself; *c, c,* are the bladders of the skin; *d, d,* are the two parallel bladders of the stomate. *Fig.* 4** represents the same parts seen from under the skin. *Fig.* 4*** shows the pellicle after the bladders of the skin and those of the stomate have been removed; the opening through the pellicle (*a*) being thus distinctly exposed to view.

Fig. 4.



It would be beside the object of this treatise to enter into an explanation of the many varieties of the stomate, especially as they are all formed upon a plan similar to that described; differing principally in the form of the constituent bladders; in their number, which is sometimes four, forming a square, or even five; and in their diameter, which, in the shortest direction, varies from the $\frac{1}{300}$ to the $\frac{1}{500}$ of an inch. But the structure of these parts in Marchantia has been ascertained by Mirbel to be so peculiar that it cannot be passed by in silence. In this imperfect plant there is no external pellicle, a slit in which forms the opening in the stomate; nor is the latter formed of a couple of bladders different in form and position from those of the skin. On the contrary, the stomate is a mere disunion and alteration in the adjustment of the bladders of the skin, with an addition to the under surface of four or five bladders which contract or expand, and thus enable the plant to respire. There is, however, very often an addition to the rim of the stomate of several tiers of bladders which rise perpendicularly from the surface. *Fig.* 5 represents some views of this kind of

Fig. 5.



structure: *a* is a stomate seen from above the skin, with the four bladders that form the contracting organ, which Mirbel calls "the obturating ring;" *b* shows a section of a stomate of several tiers, and *c* of a simple one, the contracting bladders being, in both cases, the lowest; in *b* they are shown closed up, in *c* separated and open.

The name *breathing pore*, which is often applied to the stomates, sufficiently explains that these are considered organs of respiration; and there is every reason to believe that they are really of that nature. It will be seen hereafter that the life of plants is chiefly maintained by the introduction of carbonic acid into the leaves, and the expulsion of oxygen, which results from the decomposition of the carbonic acid. From the situation, form, and other circumstances connected with stomata, it seems certain that this important function is principally performed through their agency.

From the surface of the skin often arise little processes, which, in fact are mere expansions of it, to which we give the name of lymphatic hairs, or, more commonly, hairs only, from their resemblance in appearance to the down or hair of animals. These minute

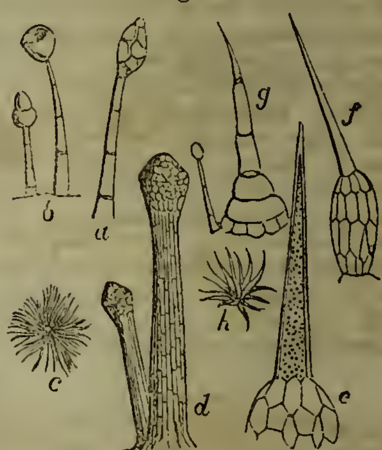
parts, which are so very fine and transparent that their structure can be ascertained only by the aid of a microscope, are usually short needle-like bodies lying nearly parallel with the surface of a plant (*fig.* 6, *a*). But occasionally they assume some remarkably different appearances.

Fig. 6.

Thus on the under side of the leaves of a little floating plant called salvinia they are jointed cylinders ending abruptly in a minute bristle (*b*); in spiderwort (Tradescantia) they have exactly the appearance of the antennæ of some coleopterous insects (*c*); in the marvel of Peru (Mirabilis) they are composed of short cylindrical joints, separated by irregular contractions (*d*). Salvinia, on the upper side of its leaves, has them consisting of a few oval joints, all of equal size, and arising from a little projection of the surface (*e*); in hawkweed (Hieracium cymosum) they are covered with short teeth (*f*); in other plants with a number of fine bristles; in Xanthium spinosum they have the appearance of a bamboo in miniature, with the joints contracted in the middle (*g*); some Boragineous plants have them armed with barbs like the head of an Indian arrow, so that they cannot be withdrawn from such bodies as they may pierce (*h*); in a kind of lavatera (L. micans) they consist of a short stalk with a tuft of finer hairs springing from the top of it like the rays of a polype (*i*); and, finally, in malpighia and the Indigo plant, they are fixed by the middle, pointing in two opposite directions (*k*).

Glandular hairs, or *glands*, as they are more commonly designated, are formed upon the same plan as true hairs, and, like them, are generally too small to be examined with the naked eye; but they have a power of secreting various substances, such as resins, odoriferous essences, or other matter which the plants require to throw off; and to enable them to perform this office, they are provided with a little bag at their point, in which the secretion is collected before being discharged. Parts of this kind are found on plants, such as the sweetbriar rose, where they appear to the naked eye as rusty dots; in the chick pea (Cicer arietinum) they consist of a slender transparent stalk, terminated by a head full of little chambers (*fig.* 7, *a*); on the shell of the grey walnut (Juglans cinerea), they are terminated by cups, in which the secreting matter is collected before it is shed (*b*); in some crotons they spring up in clusters, and gradually thicken to the point; when very highly magnified, they appear like thick stiff bodies having the form of an inverted pestle (*d*).

Fig. 7.



Stings, the office of which would seem to be to keep off aggression by the pain they inflict when inserted into the skin of animals, are stiff, needle-like hairs, which arise from a thick swollen base full of chambers, in which the poison they secrete is collected and stored up. Some of the most characteristic forms are what occur in borage, where they consist of a bristle resembling the straight blade of a poniard (*fig.* 7, *e*); in the nettle, composed of one straight rigid hair bent at a very obtuse angle from the top of an ob-conical poison-chamber (*f*); and in the gourd, where the sting is jointed,

less rigid, and gradually passes into a conical chambered base (*g*).

Scurf (or scales, technically *lepides*, whence the adjective *lepidote*, for a scurfy surface) is found on the leaves of the pine apple, the sea buckthorn (Hippophäe rhamnoides), and many other plants. It appears to the naked eye as a mealy substance of a whitish or brownish colour; but, in reality, it consists of minute scales adhering by their middle, and formed by the growing together of a number of hairs which happen to spring from one common point. *Fig.* 7, *c* and *h*, show the appearance of the scurf of the wild oleaster (Elæagnus angustifolia), when seen under a microscope.

Prickles (aculei) are nothing but hairs of a larger growth; they are hard, horny, sharp-pointed, conical, and often hooked excrescences, which rise from the surface of the stem, from which they may be easily broken off. When young, they are small, soft, and green; as the surface of a stem distends in consequence of the expansion of its inside, the base of the prickles enlarges, and, at the same time, they harden, till at last they become the large stiff bodies to which the name is applied; on the branches of the rose this their progress may be easily followed. When they are full grown, they can no longer adjust themselves to the distending surface on which they are planted, and are consequently thrown off: this is the reason why it is the young branches of plants only that are prickly, the old stems being almost always unarmed.

Chapter IV.

Of the Trunk or Caudex; difference between Root and Stem.

The central part, or axis, of a plant, to which the leaves and flowers are attached, is technically called the *caudex*, to which the English word *trunk* seems equivalent, notwithstanding its being generally applied to the thick bole of a tree.

It consists of two portions; the ascending trunk, or *stem*, and the descending trunk, or *root*. Between these there is no absolute separation, each being an extension of the other in an opposite direction; the ascending trunk, or stem, having from its earliest existence an invincible tendency to grow upwards into the air and light, the descending trunk, or root, an equally irresistible determination to the earth away from light. (See Physiology.)

The one being thus an extension of the other, there is no definite organic separation between them; but their structure melts, as it were, completely together. Nevertheless, the imaginary line formed by the divergence of these two parts has the name of *collar* or *neck*, and has been erroneously supposed to be the seat of vitality. It has been asserted, that if a tree be cut through its collar, it will never again grow. This opinion has arisen from the well-known fact, that if certain plants, such as the beech, or the pine, or the oak, are sawed through at the level of the ground, they will not shoot from the stump. This is, however, owing, not to their collar having been cut through, but to another cause: for by far the greater number of woody plants will, when cut down, throw up new shoots, whether their collar is cut through or not; as, for example, the plum, the poplar, and the rose. It arises from a specific power, which varies in different species, of forming adventitious buds, from which alone new shoots can proceed.

The great differences between root and stem consist in their organic characters, rather than in their physiological peculiarities; for many stems burrow under ground, and many roots are emitted, and can only live, in light and air, the one performing, apparently, the office of the other. The common distinction, therefore, of a root being the under ground, and a stem the above ground, part of a plant, is not sufficiently exact for science.

The real distinctions between them are the following:—A stem is divided into a number of projections called *nodes*, equidistant, or which are either at regularly diminishing or increasing distances. To each node there is usually either a leaf, or a scale, which is an imperfectly-formed leaf, and at least one bud capable of growing into a branch, which will be covered in like manner with other nodes and buds, themselves capable of again shooting into branches. Consequently, as the ramifications of a stem can proceed only from the nodes thus symmetrically arranged, the branches must, of necessity, grow symmetrically also; and hence the pleasing appearance of the

head of a tree, even when stripped of leaves. Roots, on the contrary, have neither leaves, nodes, nor buds, nor anything which can be considered analogous to them. They have no provision made for a regular ramification, which indeed could not exist in a perpetually and unequally resisting medium like the earth, but they divide and subdivide as occasion requires, without the least disposition to assume a symmetrical form.

As branches are produced by buds alone, and as roots have no buds, it is obvious that if a tree is cut down to the collar, so that nothing remains but root, it can never branch again: and hence the opinion that the collar is the seat of life. But though roots have no buds under ordinary circumstances, yet they, and all other woody parts, have occasionally the power of forming what are called adventitious buds, under special circumstances. These adventitious buds sprout irregularly from various parts of the surface; and thus in certain species of plants renew the growth which had been temporarily arrested by the destruction of the stem. No one can tell why particular species have this power, and others not; but the fact is certain. The roots of the silver fir (Abies Picea), for instance, will live on the mountains of Switzerland for half a century after the stem is destroyed (*Dutrochet*), but will never sprout again; while, on the other hand, the root of the willow will form adventitious buds, and grow nearly as readily as the stem itself.

In their internal structure roots and stems are nearly alike, except that the former are rarely hollow, although many stems are; and that in the plants called *Exogens*, which have a pith in the centre of their stem, the root has no pith.

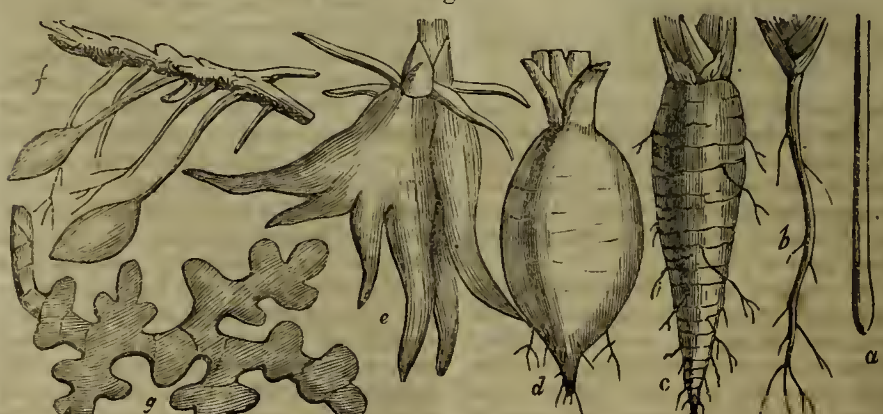
Chapter V.

Of True Roots and their Modifications; of Stems improperly called Roots.

Perhaps the most simple manner of understanding the structure of a root, limited as has been just explained, is to consider every form of that part a modification of a simple fibre.

A simple fibre consists of a cylinder, soft externally, and woody internally, ending in a blunt and succulent point (*fig.* 8, *a*), through which the fluid matter of the soil is sucked into the circulation. The aërial roots of such plants as ivy, dodder, and epiphytal orchideæ, are simple fibres altered according to the particular circumstances under which they are produced, and the modified functions they have to perform. In the dodder, for instance, they have to act as suckers as well as roots; and, accordingly, they are dilated at the end to enable them to perform that additional office. Suppose such fibres to increase in diameter principally by addition to their woody centre, and at the same time to lengthen and divide into a number of branches, each of which is like the primitive simple fibre, we shall then have a fibrous root of the commonest kind, such as that of all trees and shrubs, and of most herbaceous plants (*fig.* 8, *b*). Let it

Fig. 8.



increase much more in diameter than in length, and consist of no other ramifications than a few fibres protruded from the sides of a common centre, and such roots as those of the carrot, the radish, and the turnip, will be the re-

sult (*fig.* 8, *c* and *d*), the special figures of which will depend upon the degree in which the preponderance of growth is longitudinal, or transverse. It sometimes happens that some of the roots retain their fibrous state, while others, then called tubercles or fangs, become extremely fleshy and enlarged, as in fig wort (Ranunculus ficaria), in which the tubercles are thicker and blunter at the lower than the upper end; the roots of the dahlia and the orchis (*fig.* 8, *e*) are of a similar kind; or one portion of the root will be fibrous and the other tubercular, as in dropwort (Spiræa filipendula), (*fig.* 8, *f*). It is thought that such tubercles are intended by nature to contain a supply of food upon which the plant may exist when deprived of its usual nutriment from the earth or the atmosphere; there does not, however, appear to be sufficient evidence of the justice of this opinion. Sometimes a succulent root will ramify without increasing perceptibly in diameter, and consequently its ramifications will be all succulent and of equal thickness; such a root is that of the coral root (Corallorhiza), (*fig.* 8, *g*).

Whether or not the functions of all these sorts of roots are exactly the same is not known: their general office is, no doubt, firstly, to steady a plant in the soil in which it grows, so as to prevent its being blown about by wind; and, secondly, to suck from the earth the fluid matters which form vegetable food. The latter function may seem the more necessary of the two, but in reality the one is as important as the other; they always accompany each other, and when one is not provided for, the other appears unnecessary also. Thus, in sea-weeds, which are the only plants in which roots really seem to be unimportant, for they often grow while floating freely in the ocean, there can be no doubt that absorption of food takes place over all their surface; and it is always to be remembered that even plants like these are, at an early period of life, attached by a root, which may be supposed to perform at that time its ordinary double function. When roots are produced in the air, as in ivy, the vine in a hot damp stove, epiphytal orchideæ, and the like, it often happens that they have only the absorbing function to perform; but in such cases the business of fixing the plants steadily in their places is performed by other roots, which are emitted under or upon the surface of the ground.

In common language all kinds of underground stems are called roots; but it is necessary, both for the sake of exactness of language, and for practical purposes, to distinguish carefully between them; for while an underground stem is one of the means destined by nature for the multiplication of plants, a root will not act in that manner, except under certain special and very unusual circumstances. Neither do such stems ever appear to perform the office of roots; they seem to be chiefly intended to store up food for the use of animals. They are easily known from roots if the distinctions lately mentioned are attended to. The principal forms are the *rootstock*, the *cormus*, the *tuber*, and the *bulb*.

The *rootstock* (rhizoma in Latin) is a creeping or underground stem, which either has scales in the room of leaves, or is marked by the scars or remains of leaves that have either fallen off or withered. Of this nature are orris root and ginger; the former of which is the rootstock of a kind of iris (*fig.* 9, *b*), and the latter of the ginger plant. In the common polypody (*fig.* 9, *a*) it is a hairy body from which the leaves arise; and in the hare's foot fern (Trichomanes canariensis) it curves at its extremity like the paw of the animal after which it is named. What is commonly called a *creeping root* (soboles) (*fig.* 9, *c*) differs from the rootstock in nothing whatever except being more slender, and always subterranean, while the rootstock often lies prostrate on the surface of the ground. It has scales, which are the rudiments of leaves, at equal distances, and emits true roots from the nodes, where, also, are buds which are extremely active and ready to form new plants the instant they are placed in circumstances favourable to their development. Hence it is that couch grass, which has this sort of underground stem, if cut into pieces, forms a very vegetable hydra; for every joint is capable of growing into a new plant; and, consequently, by tearing an old plant to pieces a great number of new individuals is added to the soil, instead of one being destroyed. If it were a root, tearing it in pieces would probably destroy it. To this is also to be referred the *scaly root* of the old botanists (*fig.* 9, *d*), which is remarkable in Lathræa squamaria. It differs from the last in

nothing except that the scales with which it is covered are fleshy instead of being membranous, and that the buds at the nodes are much less active.

Fig. 9.

The *cormus*, for which we have no equivalent English word, is an extremely short subterranean stem, covered with several layers of dry withered scales, and usually having a roundish figure (*fig*. 9, *e*). It increases by the growth of the buds that exist at the axils of the scales, which, during their growth, feed upon the mother cormus, exhausting it of its soluble substance, and at last becoming cormi themselves when full grown. The root, as they say, of the crocus, the tulip, and the ixia, is a cormus.

The *tuber*, again, is a short, fleshy, underground stem, produced at the end of slender subterranean branches. Its surface is marked with scars, or covered with scales, from within which buds appear by which the species is to be multiplied. In the potato the underground branches are at first as slender as the roots among which they burrow; and are only to be known from them by their having scales upon their surface. But in time such a branch ceases to lengthen; its end then becomes swollen by the matter impelled into it, from the main stem not being able to proceed any further; it gradually increases in diameter, becomes more and more succulent, till, at last, a perfect tuber is formed, and the part of the branch not distended, decaying, separates from the parent plant as an independent individual. *Fig*. 10 shows the manner in which this takes place, and the appearance of the tubers at the different periods of their growth. When fully formed, a tuber is a fleshy body, on the surface of which are numerous depressions, each containing what a gardener calls an *eye*, which is in reality a bud, that, under favourable circumstances, will become a new plant. Hence such eyes or buds, along

Fig. 10.

with a portion of the tuber, forming together the *set*, are employed for the multiplication of a species, as in the potato. It generally happens that such eyes, like the buds on the branches of trees, do not develop the same year as they are formed, but pass the first season of their existence in gaining strength for their growth in the succeeding season. But if any circumstance should call them into action in the same season in which they are first created, a tuber will branch, and then assume an appearance very unlike its common state. This often happens to

the potato in long dry summers, when what are called clustered potatoes are generally produced. Such productions are excellent illustrations of the plan upon which tubers finally grow, and of the analogy that exists between them and branches, proving that what may appear to the superficial observer the obscure speculations of closet-philosophers, are in reality exact expositions of the plan of the creation.

The *bulb* (*fig.* 9, *f*) is a roundish body, consisting of scales packed closely one over the other, and emitting roots from its base, as in the onion. It is, in reality, an extremely short stem, covered with rudimentary leaves in the form of scales, and it differs in nothing from a bud, except that it either separates spontaneously from the part that bears it, as in the tiger lily, or it is a perfect plant in itself, as in the onion. Most commonly it lives underground; but in some lilies, alliums, and other plants, it is produced among the branches, leaves, or flowers. The tree onion is a plant in which bulbs are produced in the place of, and instead of, flowers; a singular circumstance which will be explained in another place. (*See* Chapter XXV.)

Chapter VI.

Of the Stem, and its external modifications: Spines; Tendrils.

Although the stem is, even more than the root, subject to modifications of form, yet its names are far less numerous. In its commonest state it rises erect from the earth, dividing into many branches: in herbs succulent and perishable; in shrubs and trees woody, and clothed with a thick and rugged bark. But from this state, which may be considered normal, it departs in a great variety of ways. In palms and similar trees of tropical countries it forms a cylinder, bearing a tuft of leaves at its point. In other plants it is little more than a delicate thread lying prostrate on the earth, as in the runner of the strawberry. In some species it takes a twining direction, following the sun in his course; and when of a woody structure, enfolding the largest trees with its gigantic coils. In the Museum at Paris there is a specimen of a palm-tree so surrounded by a monstrous twiner, the coils of which have grown to each other, as to be enclosed in a kind of vegetable sheath. Occasionally in the forests of tropical countries the stems of woody plants at first rise straight into the air; but not becoming sufficiently solid to support their growing weight, they gradually fall prostrate among the trees that surround them, and obstruct the traveller like cables drawn across his path. In most plants the stem is solid: in grasses and umbelliferous plants it is hollow; in a few species its bark is expanded longitudinally into green and leafy wings. These are the commonest forms we meet with in the stems of plants. Others there are which are yet more remarkable. In a kind of cabbage, called Kohlrabi, the stem shortens and distends till it acquires a globular form like that of a turnip. In the tortoise plant of the Cape of Good Hope, it is a roundish knob of considerable size, the bark of which is rent into deep fissures, separating spaces having the appearance of the scales on the back of a tortoise. Many tropical orchideous plants have a short conical stem named a pseudo-bulb, terminated by one or two leaves, and arising from a prostrate rootstock. In Stapelias (*fig.* 11, *a*), and some other South African plants, the stem becomes gouty, distorted, and succulent, bearing soft projections instead of leaves; and, finally, in the Cactus tribe it is sometimes flat and divided into a number of leafy limbs (*fig.* 11, *c*), or globular and deeply furrowed with sharp projecting ribs (*b*), or angular and erect, often rising into the air like a vegetable column.

Fig. 11.

Such are the most remarkable of the forms which occur among stems properly so called. Branches, in woody

plants, sometimes suddenly lose the power of lengthening, harden and sharpen at their points, and thus form spines, as in the sloe and hawthorn; or they lose their woody character, produce none but starved and scale-like leaves, becoming weak and curling up at their points, so as to form the tendrils by which some plants, such as the vine, contrive to climb among their neighbours. In the duckweed, and all the Lichen tribe, the stem is a flat horizontal expansion, destitute of woodiness, and apparently amalgamated with the leaves.

Chapter VII.

Of the Stem, and its internal modifications Exogens, Endogens, Acrogens.

In their internal structure stems are apparently constructed upon several different plans: in the bamboo they are hollow with transverse partitions; in the cane they are solid, and of an uniform density; in the oak they are hardest in the centre; in the cocoa-nut they are softest in the centre; in many climbers they have an uniform density, and appear pierced with multitudes of cylindrical channels parallel with the bark. In ferns the wood has a singularly twisted appearance; and, finally, in many herbaceous plants, it seems to consist of a mass of succulent substance, with a few fibres mixed among it. But it has been ascertained that all these variations are to be reduced to three primary forms, viz.: Exogens, or those which have their woody system separated from the cellular and arranged in concentric zones; Endogens, in which the woody and cellular systems are mixed together into a confused mass; and Acrogens, which consist of a cylinder growing at its point only, and never augmenting in thickness after it once is formed. We must examine each of these separately.

A stem which is formed upon the *Exogenous* plan, when cut through transversely, exhibits a central *pith*, surrounded by one or more circles of *wood*, on the outside of which is a ring of *bark*, which is connected with the pith by a number of lines passing through the wood called *medullary processes*. A branch of hazel, beech, or oak represents this structure very distinctly.

In plants whose stems exist only for a single year, there is but one circle of wood; and if such stems are very succulent, it may even be difficult to ascertain the presence of wood at all.

Fig. 12.

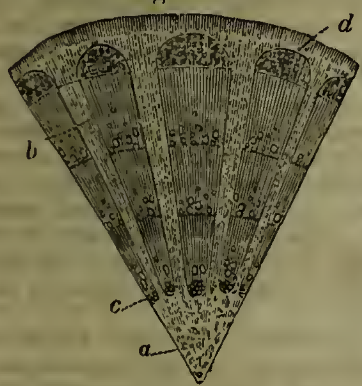
But it will always be found, upon close inspection, that some trace of woody matter exists arranged in a definite manner between the pith and the bark, separated perhaps by medullary rays, which are much thicker than the contiguous plates of wood, and which on that account tend to conceal the real structure. Such is the case in the stems and roots of many common herbaceous plants, and of cacti and similar succulent plants. Passing by, therefore, cases of this kind, the analogy of which with the exogenous structure a little consideration will serve to make apparent, let us examine in detail the exact structure of the various parts that make an exogenous stem.

The *pith* (*fig.* 13, *a*) is a spongy column which extends from the collar, where it usually ceases, to the extremities of the branches. When young it is succulent; when old it becomes dry. Usually it is solid; but in umbelliferous plants it is soon torn to pieces by the rapid distention of the woody cylinder that surrounds it, and its place is occupied by an empty tube, to the sides of which it adheres in fragments. In the walnut it is divided into a number of narrow chambers, placed over each other with great regularity. It is united with the *medullary* rays or plates, or *processes*, as they are more correctly called, by an infinite multitude of points arising from over all its surface. When young it is green and succulent, and at that time only is to be considered a living organ; its office, at that time, is to supply proper

food to the young buds which are in communication with it, until those parts, by their subsequent growth, become capable of obtaining it from other sources. After this business has been fulfilled, it dries up, and dies.

The *medullary processes* (*fig.* 13, *b*), which thus arise from the pith, of which in fact they are mere extensions, pass straight into the bark, cutting the intervening wood into a number of wedges, the broad end of which is next the outside of the stem. They are composed of the same spongy substance as the pith, squeezed in between the wedges of wood, and consequently very much compressed. In trees, the medullary plates are usually extremely thin; in succulent plants, or annual stems, they are more frequently of considerable thickness.

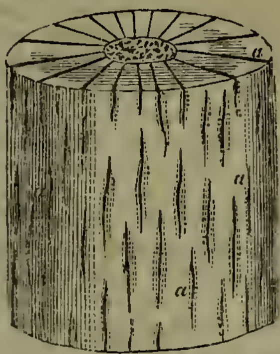
Fig. 13.



It must not be supposed, that because the medullary processes are spoken of as plates connecting the pith with the bark they are therefore of very considerable depth, or that they really divide the wood into distinct wedges. These terms are merely used to express the appearance of the parts in a transverse section of a piece of exogenous wood; in reality, the medullary plates are in general thin, and by no means deep processes, piercing the mass of wood as is seen at *fig.* 14, which represents a portion of a cylinder of wood stripped of bark, with the mouths of the medullary processes seen on the outside of the wood at *a*, *a*.

The office of these processes is very important. They are the great means of communication between the circumference and the centre of a stem, and are what enable the fluid matter, which passes down the bark, to reach the wood which is next the pith. To qualify them for performing this office the better, their component parts are placed with their longer diameter perpendicu-

Fig. 14.



lar to the bark; a position which is the most favourable which vegetable tissue could assume under such circumstances, to perform a function in which capillary attraction is the great moving power. When examined under a microscope, the component parts of the medullary processes resemble bricks placed across the fibres of the wood, and the processes themselves may be not unaptly compared to low walls stretching from the bark to the pith. This will be more particularly explained in the chapter on the elementary organs.

The *bark* (*fig.* 13, *d*) consists of two distinct parts; namely, of an external layer of a spongy substance which is usually green, and of an interior layer of fibrous matter which touches the wood, and at one time appears to be organically combined with the wedges of the latter. Of these layers, the external is called the cortical integument, and the interior the *liber*. Every year an addition of new *liber* is made, in the form of a concentric zone, within that of the preceding year; and consequently the bark would be marked with as many concentric circles of liber as it is years old; but as the wood that forms beneath the bark is perpetually straining the latter transversely, and so disturbing the relative position of its component parts, it happens that, in point of fact, the bark soon loses all trace of the concentric annual zones of liber, and becomes a confused mass of fibrous and spongy matter mixed together, its lining beirg the only part in which the liber remains undisturbed. The cortical integument, which has been justly called by Dutrochet an external pith, is sometimes soft and extremely thick, as in

the cork-tree, where it furnishes that material which proves so useful to the wine-merchant. In trees, however, it is more frequently hard and gritty, rent into deep fissures by the expansion of the wood, and mouldering under the corroding action of the atmosphere. When young it is always filled with fluid, and becomes dry only from old age. It usually has some fibrous matter mixed among its substance. The *liber* itself, although described as a cylinder of fibrous matter lining the cortical integument and overlaying the wood, is, like the wood itself, pierced in every direction by the medullary processes; so that in a section it seems to be cut into a number of wedges corresponding with the wedges of wood (*fig.* 13). Although it appears, when young, to be organically connected with the wood, yet it always separates freely when an attempt is made to tear it off, and, when full grown, the separation is made spontaneously. In some plants it is remarkable for its susceptibility of being stripped into a very considerable number of thin layers, which, in consequence of their fibrous structure, are tough enough to be employed for useful purposes. The liber of trees, before the invention of paper or parchment, was stripped into layers, flattened and cemented into leaves, upon which books were written, whence its name. In the present day, the liber of the lime tree is an important object with the Russians, who manufacture from it the coarse mats which bear their name; but the most curious instance is in the lace bark of Jamaica, in which the layers of liber are very numerous, quite white, extremely fine, and when stretched out, open into a kind of delicate net-work resembling lace. It must not, however, be supposed that nothing is liber except that young fibrous lining of the bark which we find in stripping the latter from a tree: on the contrary, it may happen that bark consists of liber on the outside as well as inside; because as bark is constantly wearing away externally, and the interior parts are perpetually pushed outwards, a time must come when the first-formed liber will reach the surface: and during the remainder of the life of such a plant the bark of its trunk must consist of liber at the very surface; such liber is, however, dead, like all the parts in contact with it. That the part of the bark which originally was internal does in time arrive at the outside of a stem is easily proved by inserting a wire into the bark of an exogen through the young and innermost liber; in a few years the wire will reach the outside, and be thrown off.

It is through the bark exclusively that the returning fluid of a plant descends to the root; and it is in this part that many secretions are chiefly stored up: for it is a remarkable fact, that in plants secreting substances of different physical properties, while one kind is freely conveyed to the central wood from the bark through the medullary processes, another part seems scarcely capable of following such a direction. Gum, for example, which so abounds in the bark of a cherry or a plum-tree, reaches the central wood in very small quantity, while a considerable supply of astringent matter passes off from the bark to the wood. To what cause this is owing has not been ascertained. It is not improbable that the gum may pass down through the woody vessels of the bark, which are not in direct communication with the medullary processes, and that the astringent matter may exclusively pass down by the parenchymatous portion of the bark, of which the medullary processes are a part.

The nature of the *wood* will be best understood by examining the structure of a single zone, and considering all the other zones subsequently formed to be merely repetitions of it. Next the pith is placed what is called the *medullary sheath* (*fig.* 13, *c*), which is a stratum of air-vessels forming a sort of casing to the pith, but interrupted perpetually by the medullary processes which pass through it. On the outside of the medullary sheath is a mixture of large vessels and fibrous matter, the former predominating; and on the outside of all, finishing the concentric zone, is a deep mass of fibrous matter, with a number of small vessels intermixed: in all the other zones exactly the same structure is repeated as long as the plant continues to grow; so that the trunk of the largest exogenous tree is a mere repetition of woody or cortical zones, the youngest of the latter being formed withinside the older, and the youngest of the former outside the older. Occasionally a small quantity of the cellular substance of the

medullary processes is interposed between the zones, as in Urtica gigas; but more frequently they touch each other without any such intervention. In some plants, scarcely any vessels are to be distinguished among the fibrous matter of the wood, or there is but little apparent distinction between the different zones; but, in the main, the structure just described is that of exogens in general.

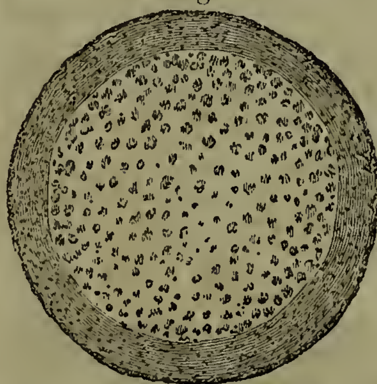
Perhaps it would be more correct to say that the woody matter is plunged into a mass of spongy or cellular substance, and arranges itself methodically in zones, than to use the language that has been hitherto employed; but this is merely a speculative point.

The anomalies which are met with in plants having this structure, however different from the normal state they may at first appear, are all easily to be reconciled with what we have described as the type of exogenous formation. Thus, in bauhinias the zones of wood are excessively irregular and unequal; in the water vine of India the medullary processes are very deep and thick, and filled with vessels; in arborescent birthworts, there is but one zone of wood, whatever the age of the stem. Finally, in calycanthus there are four centres of growth having each its own concentric zones lying in the bark at equal distances, and on the outside of the principal mass of wood. For these and other unusual kinds of structure, see *Lindley's Introduction to Botany*, &c.

Like the roots, wood has two distinct offices to perform. In the first place, it gives plants that solidity and toughness which enables them to stand erect in the air, without being destroyed by winds, or crushed by their own weight; a position which it is indispensable that the greater part of the vegetable kingdom should occupy, whether for the due performance of their own vital actions, or for rendering the earth habitable by man. In the second place, it is through the wood exclusively that the crude sap rises from the roots towards the leaves, for the better performing of which it has a simple and yet highly elaborate apparatus of tubes and vessels. The latter, which, when young, serve as conduits for fluid, become, when old, receptacles of the peculiar secretions of trees. In their young state they are nearly colourless, and form a pale mass, which we call *alburnum* or sap-wood; when old and filled with secreted matter, they become dark brown, or green, or even nearly black, in different species, and then are *heart-wood* or *duramen*. Being in this state clogged up by the matter that is lodged in them by the medullary processes, they are unfit for the conveyance of fluid, which accordingly takes place principally in the new tubes and vessels which remain open.

Endogenous stems apparently differ very much from these, for they have neither pith, nor medullary processes,

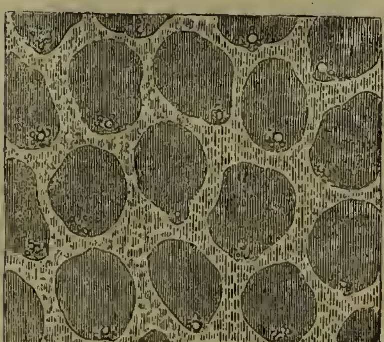
Fig. 15.



nor bark, nor wood properly so called; but they consist of a confused mass of bundles of woody substance lying in the midst of a spongy matter. In a palm we find an external cortical integument without liber; the bundles of woody matter so arranged as to be much more numerous and compact at the circumference than towards the centre. In the cane, which is another kind of palm, the woody bundles are distributed equally throughout the whole substance. In the asparagus, the aloe, and other soft-stemmed species, the woody bundles are not only equally distributed, but are so soft as to be scarcely recognised for the same thing as the hard fibres of a palm stem. Now, if we compare a stem of this sort with that of an exogen, we are, at first sight, unable to discover any analogy between them; but upon a more careful inspection, it will be discovered that the principal organic difference consists in the woody matter of exogens being arranged in wedge-shaped parcels, plunged into the spongy substance of the stem, and disposed in annual zones; while in endogens the woody matter is neither collected into

wedge shaped parcels, nor arranged in annual concentric zones, but is broken up into fibrous bundles plunged without order into the spongy mass. The correctness of this view of their analogy will be better shown, if the anatomical structure of a woody bundle of an endogen be contrasted with that of the woody wedge of an exogen. The woody bundle of an endogenous plant, if examined under a microscope, is found to be concavo-convex, with its convexity turned towards the outside of the stem. The convex part uniformly consists of compact woody matter, while vessels of various kinds traverse the concavity; an organization which is precisely that of an exogen, as has been already described. Such is the usual structure of the woody bundles of an exogenous stem. Occasionally, however, in stems of small diameter, such as the cane, the woody bundles are cylindrical (*fig.* 16), with the vessels in the interior, and a casing of hard woody matter all round

Fig. 16.



them. Another and a more remarkable deviation from the general structure of endogens is met with in grasses, the stems of which are generally hollow between the nodes where the sides are connected by transverse partitions; but the arrangement of matter in the solid shell being entirely that of palms, grasses cannot be considered to offer an exception to the law of endogenous structure. It is unnecessary to add that where stems are of very small size, corresponding modifications in the arrangement of the parts are to be expected; such, for instance, as the reduction of the woody matter to one single woody bundle, surrounded by a thin coating of cellular substance.

Arborescent Endogens being exclusively natives of hot countries, where Europeans have seldom an opportunity of examining minutely into matters which require the long and patient investigation of resident observers, nothing certain is known of the channels through which the ascending and descending currents pass in their stems. From analogy, it is presumed that the sap rises by the woody bundles, and descends through the soft spongy matter, but this is entirely conjectural.

Acrogens are totally different in their organization from both the last. In ferns, which are most remarkable both for their size and singularity of structure, the stem (*fig.* 17) is a cylinder, usually hollow; if solid, having the

Fig. 17.

centre filled with a spongy substance, destitute of bark, with neither woody bundles nor woody wedges interspersed among the general substance of the stem. The shell of this cylinder, which answers to the woody part o other plants, is composed of excessively hard plates, folded upon themselves in such a manner that a section of them represents a number of sinuous lines doubling about among spongy matter. These never increase in thickness, number, or quantity, after being once formed; but they seem as if they were, as in all probability they are, mere prolongations of the woody matter lying inside the footstalks of the leaves; whereas exogens increase by addition to the outside of their wood, and endogens, by addition, to the inside of their stem, whence their respective names have been formed. Acrogens seem to have little or no power of increase in diameter, but simply to lengthen by continual extension of their points; their name has been contrived from this circumstance.

To these principal variations of the mode of growth in the stems of plants should, perhaps, be added a fourth form, of which little notice has hitherto been taken by botanists. This, which might be called the *centrifugal*, occurs in fungi, lichens, and the lower orders of plants; and consists of a fleshy or spongy mass, or of filamentous processes radiating from a common centre.

In many respects this is the same as the Acrogenous, of which, indeed, it may be considered a mere variety; for its ramifications do not increase much in thickness after they once are formed; it nevertheless deserves to be specially explained. In an obscure plant called Marchantia, Mirbel found that a little thin green plate was first formed by the action of the reproductive grains or seedlets; and that it was from the edges of this plate, when once fully formed, that all the succeeding expansions took place, as from a common centre, but always upon the same plane; so that in such plants the central part is the oldest, and the circumference the youngest. This is very apparent in lichens, which, when very large, are always dead in the centre, while they continue to go on growing from every part of their margin. Fairy rings are an exemplification of the same thing in fungi; these appearances are external indications of the centrifugal growth of the subterranean stems of certain agarics, which originally spring from a common point, continually spreading outwards upon the same plane, the central or first-formed parts perishing as the circumferential or latest-formed parts develope.

Chapter VIII.

Of Leaf-buds.

From little conical projections from the stem, which are at first of an uniform substance, but which are eventually covered by minute scales very regularly and closely arranged one over the other, the branches of a plant are produced; and without them, no other increase in bulk can take place besides an expansion in all directions such as characterizes the centrifugal mode of growth, and such as we find in fungi. In other words, they may be said to be growing points, covered with rudimentary leaves, for their protection, and to consist of a highly-excitable mass of parenchymatous matter originating in the pith, and possessing a special power of extension in length.

Such conical projections are called *leaf-buds*. They are normally (that is, under common circumstances) formed exclusively at the nodes and from the axil of a leaf. Even in the very infancy of a plant, while it is yet in embryo, they appear at the axil of the seed-leaves or cotyledons, when they are called the *plumule;* and at every successive stage of growth they are ultimately produced as the leaves expand.

Although they appear to be mere projections of the surface, yet in reality they are not so; but are intimately connected, for most important reasons, with the very centre of the stem. In exogens they universally originate either from the termination of the pith, or at the outer end or mouth of one of the medullary processes, of which they are, in fact, an external prolongation, and by which they are, consequently, in direct communication with the pith. In endogens, their origin has not been traced with the same exactness; but there seems no reason to doubt their originating in the pulpy substance which in these plants corresponds with the medullary system of exogens.

Being axillary to leaves, they are consequently confined to the nodes, of which they are, therefore, an indication, as they must also indirectly be of the leaves when those organs have fallen off. Usually they grow singly; but in some plants, as in the peach-tree, they appear in greater numbers.

They most commonly lengthen out into branches; but sometimes if anything tends to interrupt or stunt their growth, they exchange their power of lengthening for that of hardening and sharpening at the point, and thus become *spines* or *thorns*, which are consequently very different from prickles. This may be distinctly ascertained by examining the wild orange, or which will do as well, the common hawthorn, in which the branches will be found in all their different stages of alteration into spines.

The analogy of a spine of this kind with other parts is not generally explained in elementary works. Yet, if the nature of a bud is correctly understood, such a structure is by no means difficult of explanation. It has already been stated that the leaf-bud

is a growing point capable of longitudinal extension. Usually it produces leaves as it lengthens, and if those organs are green and at regular appreciable distances, it forms a branch, but if they are coloured, placed close together, and differently shaped from leaves, it forms a flower; it is only when the lengthened point is absolutely naked, hard, and sharp, as in the wild orange, that it is a spine. There are several unsuspected analogies with this: one of which is the spadix of an arum, the succulent, blunt, subcylindrical, naked end of which is an undoubted form of the growing point; another is the succulent receptacle of a strawberry; a third the curious chambered disc of Nelumbium.

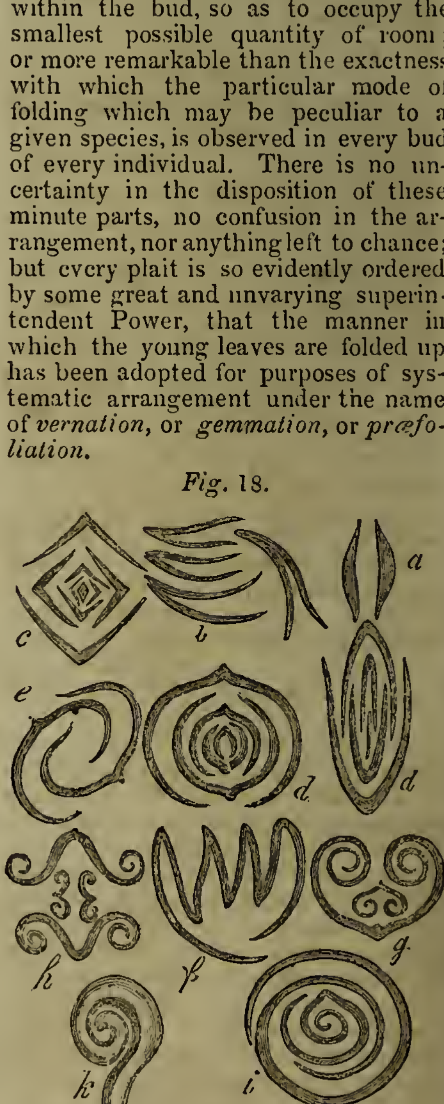
When leaf-buds appear from any other part of the stem than the node, they are considered altogether irregular in their position, and are called *adventitious*. Such, for instance, are those which often arise from the roots. Botanists are unacquainted with the cause of parts which do not habitually produce those organs occasionally giving rise to them; but it is certain that any of the pulpy or parenchymatous parts may, under particular circumstances, produce leaf-buds. Thus they are of constant occurrence at the margin of the leaves in the plant called bryophyllum; they are generated in abundance by the roots of the Cydonia japonica, and many others; and they have even been seen by Mr. Turpin sprouting from the surface of the leaves of a kind of Star of Bethlehem—not to mention other instances.

These facts explain many circumstances that would be otherwise unintelligible in the growth of plants, such as the power that roots possess of propagating an individual, and the appearance of branches from places where they would not otherwise be expected, of which we shall treat fully under Physiology. They also throw great light upon the origin of seeds.

It is sufficient to mention in this place, that the office of leaf-buds is to propagate individuals, seeds having no power to do more than increase a species; so that if a variety of any species is to be multiplied, that can only be done by aid of the leaf-buds, as is exemplified in the common gardening operations of *budding* and *grafting*, and *striking* from eyes. They, and the leaves together, are also the origin of the woody part of all plants, which first appears when the *seed-leaves* or *cotyledons*, and the *seed-bud* or *plumule*, begin to act, and which is afterwards augmented in proportion to the development of leaves and leaf-buds.

After the leaf-buds have begun to grow, and have been covered with scales for their protection, they form, beneath the scales, a number of rudimentary leaves, which are ready to unfold and augment in size with rapidity as soon as the branch is called into action. Nothing can be more curious than the manner in which these little rudiments of leaves are packed up within the bud, so as to occupy the smallest possible quantity of room; or more remarkable than the exactness with which the particular mode of folding which may be peculiar to a given species, is observed in every bud of every individual. There is no uncertainty in the disposition of these minute parts, no confusion in the arrangement, nor anything left to chance; but every plait is so evidently ordered by some great and unvarying superintendent Power, that the manner in which the young leaves are folded up has been adopted for purposes of systematic arrangement under the name of *vernation*, or *gemmation*, or *præfoliation*.

Fig. 18.



A chapter might be written upon the many different ways in which verna-

tion takes place; but we must here confine ourselves to an indication of the most remarkable, trusting to the figures which represent the plan of transverse sections of different leaf-buds, for an explanation of the terms. The principal forms of vernation are, 1st, the *appressed* (*fig.* 18, *a*), as in misletoe; 2nd, *conduplicate* (*b*), as in the rose; 3d, *imbricate* (*c*), as in the lilac; 4th, *equitant* (*d*), as in the iris; 5th, *obvolute* (*e*), as in the sage; 6th, *plaited* (*f*), as in the vine; 7th, *involute* (*g*), as in the violet; 8th, *revolute* (*h*), as in the willow; 9th, *convolute*, or *supervolute* (*i*), as in the apricot; and 10th, *circinate* (*k*), as in sundew (drosera).

Chapter IX.

Of Leaves, their position and external structure.

The stem is clothed with what are collectively called its appendages, or appendages of the axis, consisting of leaves and their modifications, and of flowers with their parts. The former, taken with the stem itself, are called *organs of vegetation* or *nutrition*; the latter of *fructification* or *reproduction.*

Leaves are usually those expansions of the bark into which slender processes of the wood and fibre insinuate themselves, and within which, after shooting beyond the surface of the stem, they expand and branch in every direction, filling the whole of the pulpy substance with a network of tough and stiff fibres, which serve to sustain the mass of the leaf. The leaf is therefore in intimate connexion with both parts of the bark on the one hand, and with the wood on the other, consisting of portions of the systems of these two important parts intimately intermingled, but each capable of acting singly as well as in concert. The pulpy substance which expands from the surface of the bark and forms the principal part of the leaf, is technically named the *parenchyma*, and the fibres that sustain it *veins*. The latter are also frequently called *nerves* or *nervures* in botanical language, although improperly, for they are merely channels through which fluids are impelled, and they have no connexion, as far as we know, with any action resembling the nervous system of animals.

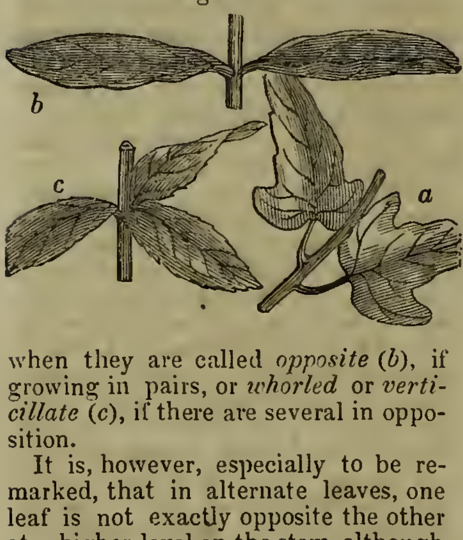
Leaves are exceedingly diversified in form, in the figure of their outline, in their position with respect to each other, in their texture, and especially in their degree of development; some leaves being nothing more than minute scales, into which the fibrous system can hardly penetrate, and others being of a size which, to those accustomed only to contemplate the foliage of European plants, must appear almost fabulous. The leaves of the bujoor palm of India (corypha elata) often measure thirty feet in circumference, and have a stalk to support them twelve feet long; so that if placed on the ground, one of these enormous leaves would be four times as high as a tall man. There is no machine of human invention, however extensive and complicated, which can for a moment be compared with such a natural apparatus as this for wonderfully elaborate mechanism. Its digesting cells are infinitely more numerous than all the houses of London and its environs; and all the streets, alleys, and passages of that huge metropolis shrink into insignificance when contrasted with the myriads of ramifications of the veins of such a leaf.

Where the bark first projects into a leaf, which is called *the point of insertion*, the leaf is usually narrow, and either round or half cylindrical, and it forms a stalk to the thin and flat part; the former is called the *petiole*, and the latter the *lamina* or *blade*. If a leaf has no stalk, it is said to be *sessile* upon the stem. The stalk of a leaf is therefore merely the channel of communication between the leaf and the stem, and may be supposed to be produced by the woody matter when it first quits the stem to form a leaf, before it begins to ramify; and it in fact consists of one or more bundles of woody matter surrounded with cortical integument. In many plants, such as grasses and sedges, it is thin, and organized exactly like the blade itself; in some plants it appears to exist without any blade, and consequently to be of itself capable of performing all the functions of a leaf, as in some strelitzias, in what are called leafless acacias, and possibly in the majority of endogens. Although, therefore, apparently a distinct organ in many cases, sometimes being even jointed with the blade, the stalk is in fact nothing but the lower portion of the leaf; and hence in all reasoning concerning identity of structure, or of

origin of parts, the stalk and blade are to be considered one and the same organ, and need not be specially distinguished. The importance of this axiom will appear hereafter.

If the branch of any plant be taken for examination, it will always be found that the leaves are arranged in some particular order; and that all other branches of the same individual, or of the same species, have the leaves arranged in the same order, so that the largest tree is merely a mass of branches, all of which are essentially the same. In all cases they arise from a node, and form one or more leaf-buds in their axil. In position, with relation to one another, they are either placed *alternately* one above the other (*fig.* 19, *a*), seemingly on opposite sides of the stem, or they arise from opposite sides of the stem at the same level,

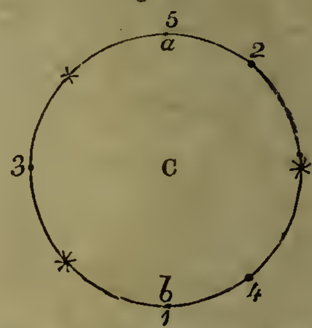
Fig. 19.



when they are called *opposite* (*b*), if growing in pairs, or *whorled* or *verticillate* (*c*), if there are several in opposition.

It is, however, especially to be remarked, that in alternate leaves, one leaf is not exactly opposite the other at a higher level on the stem, although it seems to be so, but it is placed a little to the right or left of what would be exactly a central point, and the leaf which succeeds is in like manner a little out of opposition, and so on; thus several leaves may be produced before another shall be exactly opposite to that from which the observer started. This will be clearer if we project the places of the leaves upon a circle. Let *a b*, in the circle C, be two opposite points: *b* we will suppose is the origin of a leaf, number 1; the second may appear at 2; the third at 3; the fourth at 4; and it would not be till the fifth leaf was produced that *a*, the point opposite to *b*, would be exactly touched. Now, as the wood of a branch is formed by the action of

Fig. 20.

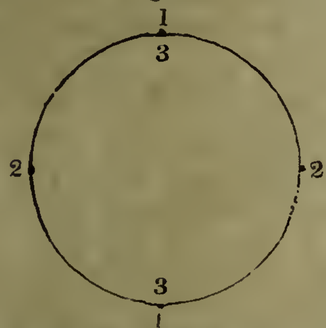


leaves, as will be hereafter shown, this is a beautiful provision of nature to insure the exact symmetry of the branches: for, although if the branch represented by the circle C consisted of but five leaves, as placed upon the diagram, more wood would be formed from 2 to 5, and from 1 to 4, than from 1 to 3, or from 3 to 5, or from 2 to 4, yet if only three more leaves were developed, those three would, upon the same principle of arrangement, be stationed in the wider spaces at *, and thus would fill up the very parts where they would be required to form wood to complete the circularity of the branch. This law is adhered to in a most remarkable manner in all leaf-bearing plants; and appears to be in reality owing to leaves being constantly disposed in a spiral manner from the base to the apex of a branch. This order is not, indeed, obvious in branches, when the leaves are very far asunder, although even in such cases it may be detected by drawing a line from the base of the lowest leaf to that of the one above it, and so proceeding until the bases of all the leaves on the branch are connected. But when leaves are small and arranged very compactly, as on the branch of an araucaria pine, or on the cone of any fir or pine, the spiral disposition is at once manifest; and in the trees called pandanus by botanists, the spiral arrangement is so very remarkable over all the branches, that they are hence called by the English screw pines.

It is not in alternate-leaved plants alone that this order of leafing is observed; even in those with opposite and verticillate leaves it takes place, only in a somewhat different manner. In opposite-leaved plants the pairs

generally *decussate*, that is, cross each other at right angles; so that the corresponding leaves of each alternate pair are placed exactly one over the other, as at *fig.* 21, where 1, 1, repre-

Fig. 21.



sent the places of the first pair of leaves; 2, 2, those of the second pair, and 3, 3, those of the third pair, which corresponds with 1, 1. The consequence of this is, that the young branches of opposite-leaved plants are usually more or less four-cornered, instead of circular

Whorled-leaved plants have their leaves placed in precisely the same manner as the last; that is, each whorl crosses that which preceded it, as in *fig.* 22, where the first whorl is represented by 1; the second by 2; and the third by 3.

That leaves such as those last described should also be reconcileable with the notion of a spiral arrangement seems at first sight improbable. But if they are studied with care, certain facts will be discovered which not only tend to render such an opinion probable, but almost to demonstrate

Fig. 22.

its truth, and that in reality all modes of arrangement in leaves are reducible to the theory of a spiral. In all considerations of this nature we must study intermediate forms and structure, and not confine ourselves to extreme cases; and in seeking to discover the analogy between the opposite and alternate forms of leafing, we must not confine ourselves to branches where leaves are invariably one or the other, but take those in which there exists a tendency to vary. Thus, in the rhododendron ponticum some leaves are opposite, some alternate. In this case we find that the leaves become opposite where the internode, or space between two leaves, is not developed; and that when it is developed, the leaves are alternate. Again, in many heaths, whose leaves are habitually whorled, or in honeysuckles, in which they are opposite, it is found, that if anything disturbs this arrangement, such as preternaturally rapid growth, the whorls or pairs separate, and the leaves become alternate, acquiring a spiral order. Again, if branches, the leaves of which, under common circumstances, are alternate, become unnaturally contracted, as in the majority of what are called stemless plants, the strawberry, for instance, the leaves, which would, under different circumstances, have been alternate, become opposite or whorled. Hence it is inferred, that when branches grow in an uninterrupted manner, their leaves are always alternate; that when they are alternately stopped in their growth, as if subject to a sort of oscillation of development, they become opposite; and that when this stoppage takes place, till three or more leaves are produced before the growth of the branch is continued, they become whorled. No cause can be assigned for such a growth and stoppage of growth in branches; but it appears to be one of those specific vital phenomena, with a knowledge of the existence of which the human mind must remain satisfied.

Chapter X.

Of Leaves continued; their usual modifications of Form.

In its usual or regular state, a leaf is a thin expansion with one surface turned towards the heavens and the other towards the earth. In this state it is liable to very numerous varieties of form, by which botanists distinguish species from each other, but into all the details of which this is not the place to enter. The greater part of these are designated by terms

which are either used in their ordinary acceptation, or, being applied to other parts as well as leaves, enter into the list of names which will hereafter be explained in descriptive botany. We shall confine ourselves to those forms which are peculiarly characteristic of leaves.

It is the opinion of botanists that the most remarkable of the forms we meet with in leaves are owing to the peculiar manner in which the veins ramify in the parenchyma; that one class of forms is produced when the veins pass straight from the top of the petiole to the margin; another class when they curve inwards, and grow to one another without touching the margin; a third, if they pass in parallel lines from the base to the apex of the leaf, and so on. And hence the arrangement of veins has been made the fundamental principle of a classification of their modifications. Although this may be carried too far, and is certainly not free from objections, it is, nevertheless, the most convenient mode which has yet been devised. Upon this principle the three following primary groups have been proposed; of each of which we shall give some examples.

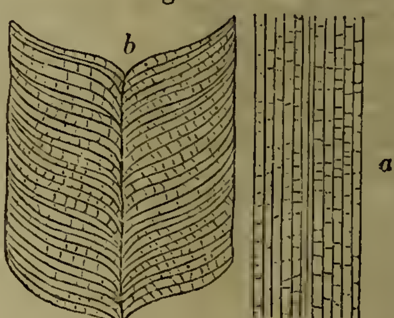
1. *Forked-veined.*
2. *Parallel-veined;* of which *straight-veined* and *curve-veined* are forms.
3. *Reticulated;* to which are referred the *ribbed,* the *radiated,* and the *feather-veined* leaves.

Forked-veined leaves are those in which the veins, whenever they divide, separate into a fork, the arms of which fork again, without forming a net-work by growing into some other veins. Instances of this are most usual in ferns (*fig.* 23), which are known by this among other characters.

Fig. 23.

Parallel-veined leaves have their veins proceeding from their origin to their termination without branching only connecting themselves by equally simple veinlets which pass off from them at right angles. Leaves of this sort are characteristic of endogens, in which they occur in two very distinct forms. The veins either pass straight from the lower to the upper end of the leaf running parallel with the mid-rib, as in grasses and lilies, whence they are called *straight-veined* (*fig.* 24, *a*), or they diverge from the mid-rib towards the margin, where they lose themselves and are called *curve-veined* (*fig.* 24, *b*), as in the Indian shot (Canna), the arrow-root plant (Maranta), and the plantain (Musa). The ragged appearance of a plantain tree, when exposed to wind, is owing to this cause: its leaves are long, heavy, and broad; and, consequently, offer much resistance to the wind; but they are also very thin, and easily torn; therefore, when this happens, the laceration will necessarily take place in the line of least resistance, which is from the edge to the mid-rib, parallel with the veins, and not across them. Palms, on the contrary, which are straight-veined plants, never exhibit the appearance of the plantain; but, if torn, rend from one end towards the other into long shreds.

Fig. 24.



Reticulated, or *netted,* leaves, are formed by the perpetual branching of veins, whose ramifications become gradually smaller and smaller; and growing to one another, divide the leaf into an infinite number of angular spaces, and form that beautiful network which is so much admired in the dissected leaves of the shops. In their most usual state the veins of these leaves proceed from the mid-rib at an angle more or less acute, towards the margin, sending off veinlets in their passage which meet and anastomoze

with the veinlets of other veins. The veins themselves curve inwards as they approach the margin, and finally grow to the back of the vein immediately before them, sending off throughout their whole length their delicate net-work of ramifications up to the very margin itself. The rose offers a familiar instance of this.

Fig. 25.

De Candolle has shown that the forms of leaves of this sort are very much dependent upon the relative proportions of the veins: thus, if all the lateral veins are short and of equal length, a leaf will be linear (*fig.* 25, *a*); if those of the middle are sensibly longer than the veins of the base and apex, the form will be elliptical (*b*), oblong, or even orbicular; but if the veins near the base are the longest and generally diminish towards the point, the leaf will be ovate (*c*); or if the longest veins are beyond the middle, obovate (*d*).

Sometimes the netted form is varied by the presence of several ribs which run side by side from the base to the apex, as in the melastoma and the dog-wood; this is called *ribbed* (*e*), and may be mistaken for a parallel-veined leaf if attention be not paid to the netting of the veins between the ribs. In another state several ribs proceed like the rays of a circle from the point where the blade and the stalk of the leaf unite (*f*), as in the poplar, and form a radiated leaf. And, finally, in the oak and many other plants in which the veins proceed straight from the mid-rib to the margin, without bending inwards, the feather-veined form is produced (*g*).

It is not by the arrangement of their veins alone that the characters of leaves are affected; they are essentially determined by the manner in which the margin is directed: for this, although in some measure dependant upon the disposition of the veins, is itself, to a great extent, an independant phenomenon.

On this subject, as upon almost all others connected with the theory of vegetable structure, the older botanists held erroneous opinions. They considered a leaf to be a body originally undivided, which, owing to some unintelligible action, became cut into segments in different ways, so as to acquire eventually a lobed structure. There can, however, be no reasonable doubt that the explanation given of its nature by De Candolle is the true one. This distinguished botanist has entered much more at large upon this subject in his '*Organographie*' than is consistent with our plan; instead, therefore, of taking his words, we shall give an explanation of our own of the theory of the structure of leaves founded upon them.

We have already shewn that the stalk of a leaf is a bundle of vessels and fibre surrounded by cortical integument or parenchyma. At a certain distance from the stem the stalk begins to branch, and each branch carries with it

Fig. 26.

its own coating of parenchyma; every separate ramification, however minute, has also its parenchymatous envelope.

Suppose the ramifications to remain perpetually distinct, and merely to develope upon a plane without touching: and we have such a leaf as the capillary many-parted one of a water ranunculus, or of a hymenophyllum (*fig.* 26, *a*).

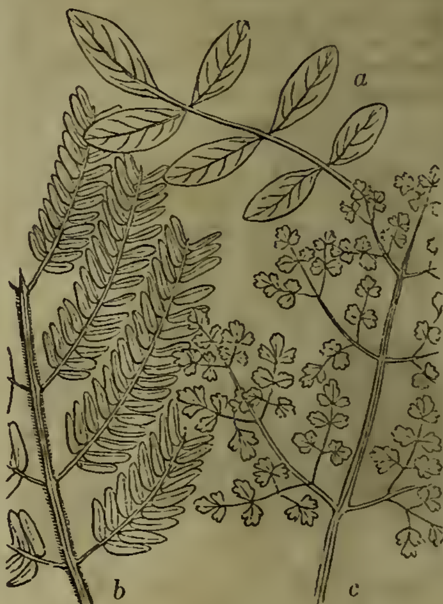
Let, however, the ramifications of such a leaf grow together at their edges in a slight degree, and a leaf like that of jatropha will be the result (*b*). Suppose the mutual adhesion of the contiguous edges take place still further, and the leaf of meadow geranium will be the result. If all the secondary ramifications of that leaf grow together, we shall have the digitate form of the common passion-flower (*c*). The principal divisions of this last united halfway up will produce a five-lobed leaf like that of sterculia platanifolia (*d*); still more consolidated, the crenelled leaf of dichondra will be the result (*f*). And, finally, if a coalition of all the exterior ramifications be completed, we shall have the entire orbicular leaf of the common asarabacca (Asarum) (*g*).

This explanation has thus been applied to a particular class of structure, —namely, the radiated; but it must be obvious that it is equally applicable to all other forms. For the terms that are employed to describe all these and other modifications we refer to the chapter upon Descriptive Botany.

There is, however, a kind of division somewhat different from this, although the same in principle, of which particular mention must be made. Suppose the primary ramifications of a skeleton feather-veined leaf to remain quite distinct, while the ramifications of all their divisions are consolidated into separate leaves, or rather leaflets, and a sort of compound leaf, such as we find in the liquorice, the pea, &c., will be produced; this is called *pinnated* (*fig.* 27, *a*). Now, imagine the skeleton of the same leaf to become consolidated in its tertiary ramifications, while the first and second veins remain distinct, and we have the bipinnated leaf of the gum acacia (*b*). It is possible to conceive the fourth order of ramifications of the venous system to be grown together, while the first, second, and third are distinct, and the unusual structure of *tripinnation*, such as is found in thalictrum, will be produced (*c*). Such divisions may be carried still farther, but the only name which is then applied is *supradecompound*.

Leaves thus deeply divided are commonly called *compound*, while leaves which are less than pinnated are said to be *simple;* but these terms are now

Fig. 27.



restricted otherwise. When a petiole is jointed with the blade, or with the leaflets, the leaf is considered compound, whether the blade be undivided or not; and, on the other hand, the most deeply or frequently divided leaves are considered simple, if no articulation exists between the blade and the petiole. Thus the leaf of an orange is compound, of a palm simple.

Chapter XI.

Of Leaves continued; their unusual modifications of Form.

Besides the variations in the external structure of leaves treated of in the last chapter, there are others which, being exceptions to general rules, deserve to be noticed separately.

These exceptions are chiefly owing to five causes, or to a combination of more than one of them, namely, 1, a turgid state of all the parts, owing to the parenchyma being excessively succulent; 2, a general or partial diminution in size; 3, an excessive expansion of particular portions; 4, an unusual contraction and hardening of parts which are generally broad and leafy; and 5, the growing together of parts which are usually distinct.

It is to the extreme succulence and

consequent distention of the parenchyma in a particular direction that the singular leaves of the mesembryanthema are indebted for their curious forms. In one species they are *scimetar-shaped* (acinaciform) (*fig*. 28, *a*), because the parenchyma increases in thickness from the front to the back, while the width is not augmented in a corresponding degree; in others they are *axe-shaped* (dolabriform) (*b*), or deltoid (*c*), from the action of the same cause in a different direction; or they may be cylindrical conoids (*d*), as in mesembryanthemum barbatum, or the

Fig. 28

common onion, in which latter they are also hollow, because the circumference of such a leaf grows faster than the centre, which is in consequence torn and left without parenchyma to fill it up.

A general or partial diminution in the size of parts produces some great deviations from the usual structure. If all the parts are reduced to their smallest size, such leaves as those of the moss, which are mere minute and thin scales, or of lathræa and similar parasites, which are larger and more fleshy, but still mere scales, may be the result. But if the diminution in size take place only partially, it will simply be attended by a loss of symmetry, which will hence cause remarkable changes in appearance. In Begonia, for instance, one side of the leaf is considerably smaller than the other, and it becomes what botanists call *oblique*, or one-sided (*fig*. 29, *a*); in a pinnated leaf, the leaflets of one side may disappear, as in anthyllis and others (*b*). These circumstances are always caused, according to De Candolle, by the situation of such leaves upon the stem being more favourable to the development of one side than of the other; but this statement is scarcely borne out by facts, which seem rather to stand isolated and incapable of explanation from any secondary cause.

Fig. 29.

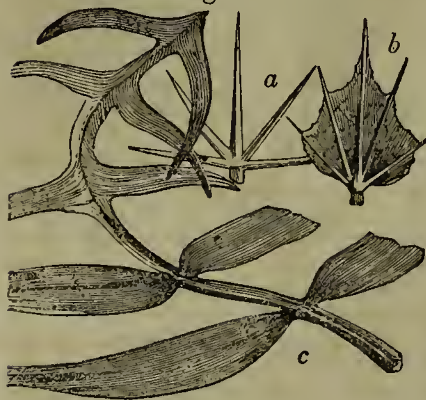
The excessive expansion of particular portions is much more frequently productive of singularity of form than any of the preceding. The expansion of the petiole in the orange (*fig*. 30, *a*), and the dionæa gives that part very much the appearance of a leaf; a similar structure in the compound leaf of a begonia from Madagascar, combined with the non-formation of leaflets, converts the petiole into what has been called a lomentaceous leaf (*b*); and a similar loss of leaflets connected with an excessive expansion of the petiole forms the *phyllodia* of the so-called leafless acacias of New Holland (*c*, *d*, *e*).

Fig. 30.

When certain parts of the leaf contract and harden, *spines* are formed, as in the edges of the common holly leaf, where the hardening is confined to the lobes; and in the berberry, which has the principal veins of its leaves separated and hardened (*fig*. 31, *a*, *b*). In a species of prosopis, the one half of the leaflets contracts into a spine, while the other half remains leafy. But the most singular instance of this kind of deviation from usual structure occurs in a palm called desmoncus (*c*), in

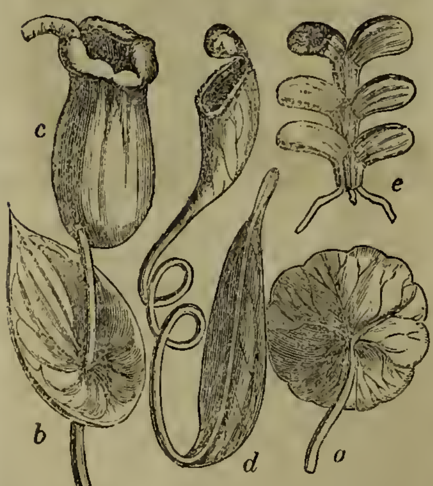
which the upper leaflets of its pinnated leaves contract and curve into scythe-shaped hooks by which the desmoncus climbs, while the lower leaflets retain the usual appearance of leaves.

Fig. 31.



But none of all these causes produces so strong an effect upon the general appearance of a leaf, or tends so much to render it unlike itself, as the adhesion of one part to another, especially if accompanied by some of the alterations already spoken of. Thus in the iris the leaves resemble the blade of a straight sword with one edge turned towards the sky, and the other towards the earth. This, which is called *equitant*, is caused by the leaves folding up, and their faces forming an adhesion with each other (*fig.* 32, *e*). In the nasturtium (*fig.* 32, *a*), the two

Fig. 32.



lobes of the base of the leaf grow together, so that the stalk looks as if it proceeded from the middle of the leaf, the latter becoming what is called *peltate*. In the honeysuckle the stem seems to grow through the leaves, in consequence of the base of two opposite leaves adhering; a similar appearance is produced in bupleurum, by the bases of each alternate leaf curving round the stem, and then growing together into a *perfoliate leaf* (*b*). But it is when a leaf, or some part of it curves inwards till the opposite margins touch, and then grow together, that the most singular appearances are produced. What are commonly called pitchers originate thus. In some species of dischidia the blade of the leaf acts thus, and at the same time becomes enlarged and succulent; the consequence is a sort of leathery bag (*c*), in which the plant carries to the tops of trees the water it requires for its support. In the side-saddle flower (Sarracennia) it is the whole petiole which is thus affected, the blade of the leaf remaining unchanged, and acting as a sort of lid to the pitcher; while in nepenthes, or the true pitcher plant of India (*d*), the petiole is partly round, and, in its common state, partly expanded into the form of a leaf, and partly rolled up into a pitcher, leaving the blade of the leaf at its extremity as a cover to the pitcher.

Thus it appears that all the varied forms of leaves are to be reduced to one primitive type, from which they are deviations, and which are to be explained upon perfectly simple and intelligible principles. It will hereafter be seen that the leaf is the type of forms still more remarkable than any now mentioned, and having a totally different class of functions to perform.

Chapter XII.

Of Leaves continued; their internal Structur

The universal presence of leaves upon all plants, their highly complicated structure, the intimate connexion which it has been shown that they maintain between the systems of the wood and bark, their extremely high development in many cases, and their multiplied variety of form, all lead to the opinion that they are organs of the most essential importance. This is confirmed by their internal structure, independently of experiment.

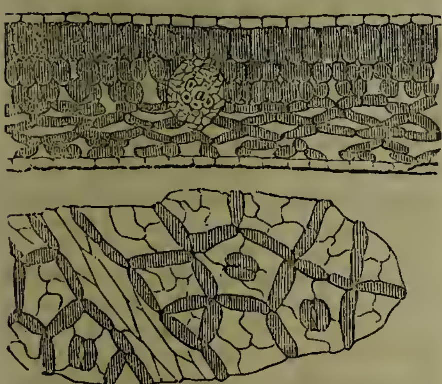
Most leaves are no thicker than a piece of paper or parchment, and appear to the naked eye as nothing more than a thin green plate, so that an

ordinary observer would never suspect that their internal structure, which no eye, unassisted by glasses, can investigate, was one of the most complicated and highly-organized character; and yet there is no part among those with which plants are furnished which is more complex. It is necessary, indeed, that it should be so, in order to be enabled to perform the important functions of digestion, respiration, and perspiration, for which it is destined.

This subject has been very carefully investigated by Messrs. Mohl, Adolphe Brongniart, Meyen, and Mirbel, to whom we are chiefly indebted for our knowledge concerning it. Perhaps the most simple mode of explaining the result of their observations will be to take some common kind of leaf as a type, of which all others may be considered modifications. For this purpose we will select the apple.

The leaf of an apple-tree (*fig.* 33)

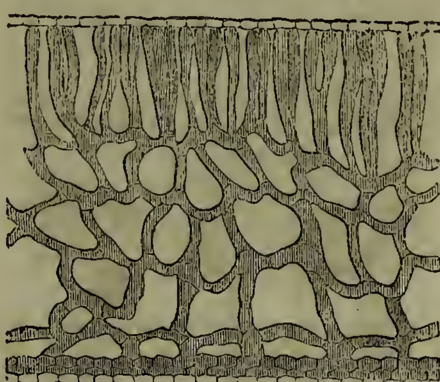
Fig. 33.



consists of a mass of parenchyma, through which pass bundles of vessels and wood tubes in the form of veins; the whole of which is enclosed between two extremely thin plates of cuticle which are united at the edge of the leaf. This cuticle consists of a single layer of minute bladders containing air, and pierced with stomates which are generally much more numerous on the under than on the upper side. Beneath the skin of the upper side are about three layers of cylindrical bladders filled with green pulp, which are packed closely together *perpendicular* to the skin, but with minute cavities between the bladders, and more open spaces caused by the total separation of the bladders beneath each breathing pore. Beneath the skin of the under side are four or five layers of similar cylindrical bladders lying *parallel* with it, touching each other only at their ends, and forming the sides of a number of chambers which communicate freely with each other. This lower layer joins the upper layer, thus dividing the whole of the inside of the leaf into two portions, the constituent parts of which are perpendicular to the upper surface and parallel with the lower; the upper, where the skin has comparatively few stomates, being very compact, the lower, where the stomates are numerous, being very lax and cavernous; a beautiful adjustment of parts most admirably adapted to the functions of the leaf, as will be hereafter shown.

This is the common structure; that side of the leaf being the most cavernous where there is the greatest number of stomates, and the reverse. Thus, in the water lily (Nuphar) (*fig.* 34), in which the lower side of the leaf has no stomata, the compact structure of bladders is on that side, and the cavernous parenchyma is on the upper, where the stomata are extremely numerous.

Fig. 34.



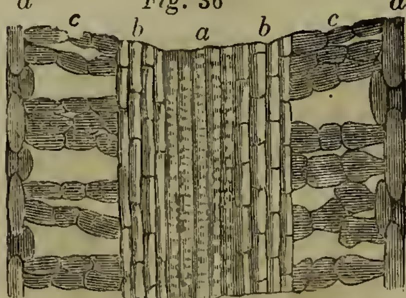
In succulent plants, whose leaves have neither upper nor under surface, the parenchyma is of equal density throughout; in leaves which are constantly under water, as in many floating plants, the skin is entirely absent, and the cavities of air are distributed equally through the whole mass of the parenchyma (*fig.* 35); and in thin leaves, such as the Iris, the two sides of which are exposed alike to the action of light, in consequence of their edges being vertical instead of horizontal; the parenchyma next the skin is cavernous on both sides with perpendicular bladders,

while the centre is often filled with compact parallel bladders. The fol-

Fig. 35.

lowing section of the leaf of a pine-tree (*fig*. 36), copied from Adolphe Brongniart, in which *a* is a bundle of vessels, *b b*, parallel compact bladders of the centre; *c c*, the perpendicular bladders of parenchyma filled with air cavities; and *d d*, the skin of the two surfaces, illustrates this.

Fig. 36



In plants with a hard cuticle, that part is often formed of several layers of empty bladders, as in the oleander; and in mosses, and plants which have very imperfect leaves, two or three layers of thin-sided bladders often constitute the whole mass, without distinction of skin from parenchyma.

In marchantia, the structure is, if possible, still more remarkable than in the instances already cited. This plant, which, in the hands of Mirbel, has been the subject of the most profound and complete examination that has yet been instituted in vegetable physiology, has been found by that skilful observer to consist, on its under side (*fig*. 37, *a*), of a thick layer of nearly empty bladders, firmly arranged without air cavities, and not covered by skin; but on its upper surface (*b*), where alone stomates occur, it is covered by a skin, beneath which the parenchyma is filled with green pulp, and

Fig. 37.

divided into a multitude of lozenge-shaped chambers completely cut off from one another, but giving rise to numerous jointed deep green processes which spring from their sides, and partially fill the chambers (*c*).

As in common leaves, these chambers also communicate with the stomates, which in marchantia may, without exaggeration, be compared to chimneys, through which ventilation is carried on (*d*).

What has hitherto been stated refers only to the parenchymatous structure of leaves. The venous system which pierces them in every direction consists of vessels surrounded by woody tubes, which stiffen and protect the former (*fig*. 33 and 36, *a*): these are largest near the base of the leaf, and gradually diminish in thickness towards the extremity of their ramifications, till they altogether lose themselves in the parenchyma. To the eye, aided by the most powerful microscopes, the veins seem to be altogether single: but it is well known that when a leaf has been macerated till the parenchyma is quite decayed, the veins will separate into an upper and a lower stratum, so neatly and regularly, that it is impossible to doubt their having

originally consisted of two distinct systems, the one placed above the other. As the sap is propelled from the wood into the leaf in a crude state, and returned into the bark in an elaborated state, and as the veins of leaves are evidently connected with both the wood and the bark, it is supposed that the upper of the two layers is for the onward flow of the crude sap, and the lower layer for the backward flow of the elaborated sap; but there is no distinct evidence of this opinion being well founded.

The anatomical structure of the leaf appears distinctly connected with its functions of respiration and evaporation. That side of the leaf which is next the sun being most exposed to heat, the cylindrical bladders that form it are placed with their narrow ends next the cuticle, by which means they not only each present the smallest evaporating surface, but are so circumstanced with respect to each other, as to be able, with the least difficulty, to absorb fluid from each other as they empty. The bladders next the lower surface not being exposed to the same kind of external influence, do not require the same kind of internal adjustment of their parts, but are arranged with wide intervals between them, which communicate with the chambers below the numerous breathing pores of the lower surface. Here, then, the functions of respiration are best performed, each bladder, on the one hand, exposes the greatest possible extent of surface to the action of the oxygen or carbonic acid that may be received by the breathing pores, and has, on the other, the greatest possible power of parting, firstly, with the oxygen, which results from the decomposition of the carbonic acid in these vegetable stomachs, and secondly, with the superfluous water, which is not evaporated by the upper surface through the cuticle. It will be observed, that in the water-lily (*fig.* 34), in which the most cavernous part of the parenchyma is next the upper surface, the leaf floats with its lower face upon the water, respiration consequently cannot take place at the under surface, and the function is of necessity transferred to the upper, where the stomata all are.

From these statements it is to be inferred that leaves are a sort of pneumatic apparatus, of a highly-curious and elaborate structure; and that the variations which occur in their internal organization are beautiful adaptations of the parenchyma to the particular circumstances under which the leaves themselves are placed.

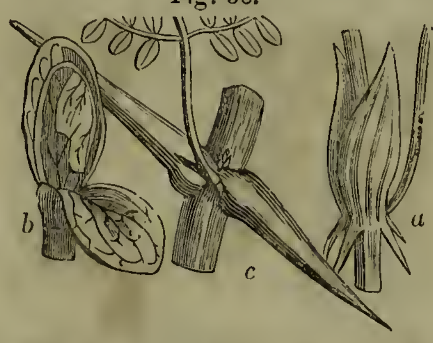
Chapter XIII.

Of Stipules, Tendrils, and Hooks.

The *stipules* are, in many respects, analogous to leaves; like those organs they are often green, lobed, or otherwise characterized; they frequently have buds in their axils, as in the peach and the willow; and they sometimes are not distinguishable from leaves by anything in their form, colour, or consistence. Nevertheless they are, in most cases, sufficiently different from leaves, and are always to be recognised by their position at the base of a leaf, one on each side.

In their most complete state they are little leafy bodies, as in the vetch (*fig.* 38, *a*) and the pea; they are large, lobed, green organs in the heart's-ease (*fig.* 1, *d*); in the tulip tree they are flat, oblong, undivided membranes (*fig.* 38, *b*); in the bird cherry they are

Fig. 38.



nothing more than fine green bristles; and in other plants, as buckthorn for instance, they are frequently reduced to the state of a minute withered scale. By hardening and becoming conical, they resemble spines in some mimosas (*c*); and by losing their parenchyma, and lengthening their mid-rib, they are transformed into long, soft, thread-like processes, which will twine round neighbouring bodies, and thus support the weak and slender stem in the air, as in gourd-like plants. They are then real tendrils.

By adhesions either with each other, or with the leaf, they sometimes alter their appearance in a remarkable de-

gree. In magnolia, they grow together by their upper end, and rolling round the young buds, form a long horn-like sheath, which effectually protects them till they are ready to unfold. The pondweed (potamogeton) has a structure analogous to the last (*fig.* 39, *d*). In cinchonaceous plants they adhere sometimes by one edge, sometimes by another; but most commonly the two contiguous stipules of a pair of opposite leaves unite by their edges, and grow into a scale placed between their two footstalks, which is called an interpetiolar stipule (*fig.* 39, *c*). In polygonum they are thin, rolled round the stem, and united to each other by both edges, so as to form the sheath to which the name of *ochrea* is technically given (*b*). In the rose they grow to the edge of the footstalk, of which they become a thin, leafy margin. And finally, in alternate-leaved plants they are sometimes large enough to surround the stem and unite where they meet on the side opposite to the leaf, which is then called *synochreate* or *hypoglottideous*, as in many species of astragalus (*a*).

Fig. 39.

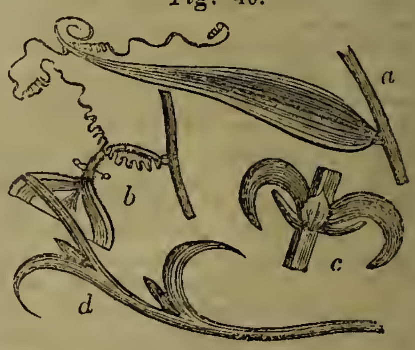
Many other modifications might be pointed out; those now explained will serve to show that the stipules are such variable organs, that neither form, texture, size, nor colour will define them; but that they are simply characterized by being placed *at the base of the leafstalk.*

The use of stipules in their most complete state is supposed to be to protect the young leaves; such at least seems to be the case in species whose stipules are very highly developed: in the fig and magnolia, for example, they roll round the leaves till the latter are large enough to burst through them, and are able to bear exposure to the air without injury and in the tulip-tree (Liriodendron tulipifera) they act like two dishes which fit together by their edges, and enclose the young leaves in their concavity (*fig.* 38, *b*). But it is difficult to believe that protection is the only office these organs have to exercise, for in by far the greater number of cases they are so small as to be unable to perform any such purpose. If instances of their being rudimentary bodies were rare, instead of so very common, it would be easier to believe that the business of stipules is really that which is assigned to them.

Tendril is a name given to any part of a plant which is thread-like and capable of twisting round neighbouring plants; it cannot, therefore, be referred to any particular class of organs. In the vine it is a transformation of flowering branches; in the gourd it is an altered stipule; in the pea it is the extremity of the petiole; in gloriosa it is the point of the leaf (*fig.* 40, *a*), which is nearly the same thing; in nepenthes it is the cylindrical part of the petiole; and in the singular genus strophanthus it is actually the points of the petals which have become tendrils, and twine round other plants.

Hooks, which, like tendrils, are contrivances by which weak plants cling to those that are stronger, are also mere adaptations of other organs to that purpose. The hooks of uncaria (*fig.* 40, *c*) are abortive branches, leafless, spiny, and very much curved; those of combretaceæ are produced by the hardening of the petiole after the leaf has withered; and in the singular genus ancistrocladus they appear to be also petioles, but of leaves which never develope in any other form (*d*).

Fig. 40.



Chapter XIV.

Of Bracts.

All the parts hitherto treated of belong to what are called *the organs of nutrition or of vegetation.* Their office is so strictly conservative, that nothing has been assigned to them beyond the power of absorbing crude food from the earth by the roots, altering it a little in the stem, digesting and separating it in the leaves, and storing up in the bark and wood the matter thus altered and inspissated. Every thing which is developed subsequently to the leaves belongs to the *organs of reproduction* or *of fructification;* the sole office of which is to secure the perpetuation of species by seed,—an action they are enabled to perform by the nutrient properties of the stem and leaves.

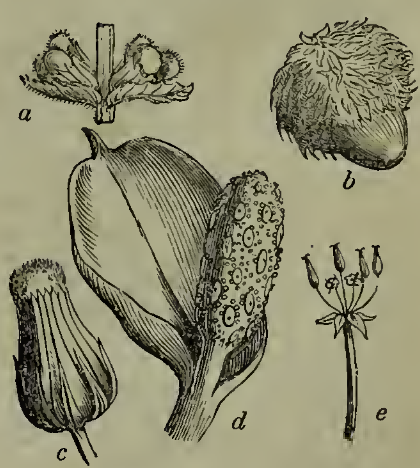
A little below the flower, interposed between it and the leaf, from the axil of which it arises, are, in the Heart's-ease, one or two little scales, which are evidently organs in an exceedingly rudimentary state. Botanists call them *bracts* (*fig.* 41, *a*), and suppose them, when sufficiently large, to be destined for the protection of flowers before they unfold; but they are frequently in an extremely imperfect state, and quite unfitted for such a purpose.

Although bracts are so exceedingly minute in the Heart's-ease, and, in such plants as we are most in the habit of examining, are seldom so large as ordinary sized leaves, or of any other colour than green, yet they are sometimes of remarkable dimensions, and coloured white, or purple, or crimson, or some other gay tint, and then receive the especial name of *spathe* (*fig.* 41, *d*). An instance of this we find in the Cuckooflower of our own hedges (Arum maculatum); in some foreign Arums the spathe is very much larger than in our indigenous species; but it is in Palms that this part acquires its most extraordinary dimensions. The spathe of Alfonsia amygdalina, a South American species, is computed to contain upwards of 200,000 flowers; and that of Corypha Taliera, an East Indian palm, is often as much as twenty feet long.

When bracts are collected into a whorl, as in umbelliferous plants, they are said to form an *involucre* (*fig.* 41, *e*), which, if very small, receives the diminutive name of *involucel.* This kind of organ is very remarkable in compound-flowered plants, appearing as if it constituted a calyx common to many flowers (*fig.* 41, *c*); and hence it used to be called a common calyx. It however does not differ from the involucre in any thing more than its bracts being more numerous, more closely packed, and parallel with each other, instead of diverging. *Periphoranthium* and *periclinium* are names given by foreign botanists to this kind of involucre.

Sometimes bracts not only collect in a whorl, and grow parallel with each other, as in the true involucre, but they actually grow together into a solid cup-shaped body, their points only remaining distinct: such is the cup, or *cupule,* of the acorn (*fig.* 41, *b*). The real nature of this part is not very obvious in our wild oaks, but it may be distinctly observed in the cupules of the mossy-cupped, or Turkey oak (Quercus cerris), which is common in plantations. If the young acorns of that species are examined, the cup will be found to consist of numerous whorls of bracts loosely cohering, and evidently not distinguishable from common bracts; as it gets older they grow together by their lower ends, till at last the acorn cup is fully formed. In Grasses and Sedges the flowers seem to be composed of nothing but bracts, in different states, packed closely one over the other; in these instances we must suppose they perform the office of calyx, whatever that office may be.

Fig. 41.



Bracts being thus variable in their appearance, their limitation becomes proportionably difficult. The best perhaps is that which defines them to be all leafy bodies which intervene be-

tween the calyx and the leaves. To this, however, the impossibility of determining, in some cases, where the calyx begins, is an objection. (See Chap. XVI.) Difficulties of this kind arise, out of the very nature of things, and are consequently not to be overcome, as will be hereafter explained. (See Chap. XXV.)

As all leaves have the power of forming leaf-buds in their axils, so have all bracts the power of forming flower-buds in their axils; and it rarely happens that flowers occur which do not thus originate. Hence it is a general rule, that where bracts are found, flowers may also be expected.

Chapter XV.

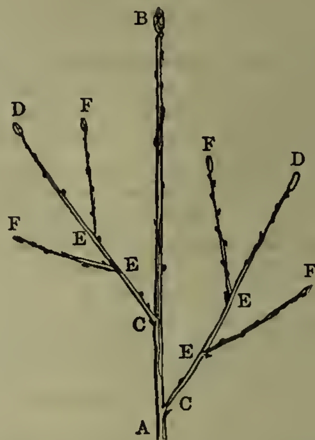
Of the Inflorescence.

The manner in which flowers are arranged upon a stem, or, more correctly, upon that part which bears the flowers without lengthening into a leaf-bearing branch, is called the Inflorescence. A variety of different forms is mentioned by botanists, and it is found necessary to distinguish them with care for systematic purposes; but they are, in reality, all modifications of two primitive types, which, if well understood, will readily explain the origin of the others.

In order to make this intelligible, we must consider upon what principle branches ramify. When an embryo plant shoots up its first stem, it is terminated by a growing point, which keeps leaving leaf-buds behind it on the surface of the stem as it lengthens. This growing point finally occupies in the winter the centre of that leaf-bud by which a stem is terminated, and again lengthens in the spring when vegetation is renewed. Let us call the stem of the first year, with the leaf-bud at its extremity, the *primary axis* (*fig.* 42, A B); this part is covered with other leaf-buds, which, when they lengthen, do so upon exactly the same plan as the first, each having its own growing point, and forming a *secondary axis* (C D), which itself, in like manner, generates *tertiary axes* (E F), and so on.

Now, the inflorescence of a plant obeys the same laws of branching; only for leaf-buds we have flowers. And the two primitive types to which all modifications of inflorescence are reducible, depend upon whether the growing point of the primary axis has the power of lengthening indefinitely or not. If it have the power of growing indefinitely, inflorescence is said to

Fig. 42.



be *indeterminate;* if its powers of lengthening are uniformly arrested at an early period, inflorescence becomes *determinate;* these being the original causes of the various forms of branching we meet with among flowers.

§ 1.—*Indeterminate Inflorescence.*

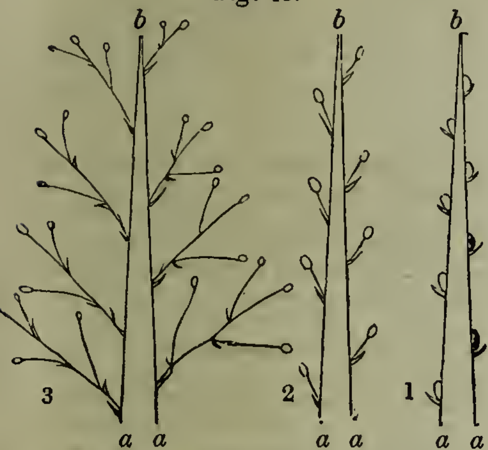
The characteristic of this is, that the primary axis is not arrested in its growth at a very early age, but its secondary, tertiary, or other axes are; and it comprehends some of the most common modifications. Let the lines *a a*, *b* (*fig.* 43), represent such an axis, the lateral buds or secondary axes of which are flowers. As those buds which are nearest *a a* were the first formed, they must of course be the oldest; they will therefore be the first to open; and consequently the flowers, when they expand, will do so first at *a a*, and last at *b*, or in an ascending order. This order of flowering is called *centripetal*, because *a a* is considered to represent the circumference of a cone of which *b* is the apex or centre. Now, suppose that while the primary axis *a a*, *b*, is indeterminate, all the secondary ones *o*, *o*, *o*, are determinate, and have no power whatever of lengthening (*fig.* 43, 1), an inflorescence will be produced analogous to that of the Rib-grass (Plantago): this is called a *spike;* or if it only bears barren flowers, and drops off after shedding the pollen, as in the Hazel, an *amentum* or catkin; or if it is covered very densely by flowers, and is enclosed within a spathe,

as in Arum, it receives the name of *spadix*.

But if the secondary axes *o*, *o*, *o*, have the power of lengthening equally, without however producing tertiary axes, a *raceme* (*fig.* 43, 2) is the result, as in the Currant.

And if the secondary axes develop tertiary axes (*fig.* 43, 3), a *panicle* will be formed, as in Poa annua, which will be more or less compound according to the number of degrees of its ramification. When the upper and lower branches are shorter than those in the middle of a panicle, as in the Lilac, we have a *thyrse*.

Fig. 43.



§ 2.—*Determinate Inflorescence.*

Forms referable to this type are distinguished by the primary axis being arrested in its growth, before the purposes of flowering are at an end; the consequence of which is, that determinate inflorescences, if consisting of more than one flower, are broad instead of being long. A solitary flower, such as that of the stemless Gentian, is taken as a type of this. It consists of a primary axis terminating in a single flower. An idea of it may be obtained from *fig.* 44, 1, in which the lines *a a b* represent the primary axis, bearing bracts from which secondary axes do not arise.

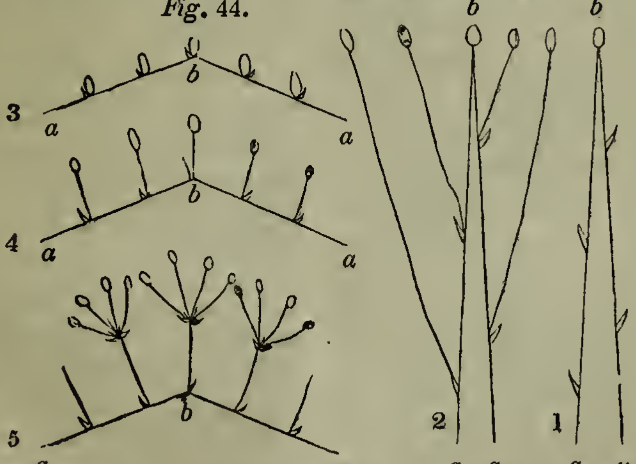
Now, let secondary axes arise from this, of which the lowest are longer than the uppermost, and each long enough to be elevated as high as the central flower, and we have a *corymb* (*fig.* 44, 2).

Suppose the primary axis to be exceedingly short, and the buds of secondary axes to be closely crowded upon it; if, in such a case, the secondary axes do not lengthen, but merely unfold their flower, as in *fig.* 44, 3, a head or capitulum, like that of the Dandelion, is the consequence, in which the axis is distended laterally, in order to make room for the flowers.

But if, while the primary axis is very short, the secondary axes lengthen partially so as to form stalks to the flowers, as at *fig.* 44, 4, an *umbel* will be formed, which umbel will become *compound*, if the secondary axes develop upon the same plan as the primary (*fig.* 44, 5).

Hence it is evident that the head is a spike with a short primary axis, the umbel a raceme, and a compound umbel a panicle in the same condition. All these forms follow the centripetal order of flowering.

Fig. 44.



But there are other determinate forms of inflorescence in which a *centrifugal* order takes place; that is to say, in which the uppermost, or most

central, flower opens first, and the lowermost, or most external, last. In these cases the theory is, that it is not till after the central flower is formed that the lateral ones begin to develop, and that consequently the central flower, in such instances, is really the oldest. A bit of the Laurustinus (Viburnum tinus, *fig.* 45) shows this very well.

Fig. 45.

If this sort of centrifugal development resembles a panicle, or rather an irregular umbel, as in the Laurustinus, it is called a *cyme.*

When what would otherwise be a capitulum expands its flowers centrifugally, it is called a *glomerule.*

And if a cymose arrangement of the parts is much contracted and but little branched, as in a Sweetwilliam, we have the *fascicle.*

Chapter XVI.

Of the Floral Envelopes.

A perfect flower consists of three principal parts; namely, the *floral envelopes*, the *fructifying system*, and the *fertilizing system.* Of these the two last are always present, either both together or in separate flowers; the first may be either present or absent, not being essential to a flower.

The floral envelopes generally consist of two different parts, the calyx and the corolla: wherever these can be distinguished, they are spoken of separately; and it is probable that their respective office is, in that case, different also. But it frequently happens not only that these organs run so much into bracts as not to be readily distinguishable from those parts, but that they pass so gradually into each other, that although from the appearance of the external of the floral envelopes we may consider these calyx, and from that of the internal ones we can suppose those to be corolla, yet we are quite at a loss to know where the outer ends, and the inner begins. This happens in the Carolina allspice (Calycanthus), the white Water-lily (Nymphæa), and various other plants. To designate such cases, the word *perianth*, or *perigone*, has been contrived; and in descriptive botany is employed to express floral envelopes consisting of several whorls of parts passing gradually into each other. This seems to show that whatever the calyx and corolla may be, they are extremely similar, or, indeed, identical in nature.

In some cases the parts of which they are composed are green like leaves, particularly in the calyx; but most frequently they are thinner, more delicate, and of a colour not green. They are usually destitute of the hard fibrous texture of leaves, for which indeed they have no occasion, their existence being usually very transitory; they are, however, pierced by air-vessels, which are arranged somewhat upon the plan of the veins in leaves, and they are amply supplied with stomates. The tissue of which they consist is uniformly colourless and transparent; and the gay colours by which they are so generally remarkable, are caused by minute drops of coloured fluid lying in their cells. Such drops are therefore separated from each other by minute air-cavities or plates, and this is probably the cause of the beautiful satiny lustre we find upon almost all petals.

The manner in which the pieces of the floral envelopes are respectively arranged in the flower-buds is called their *æstivation*, and has received certain distinctive names, of which the following are the most remarkable.

Valvate, when the pieces fit exactly to each other by their edges, as in the calyx of the Mallow (*fig.* 46, *a*).

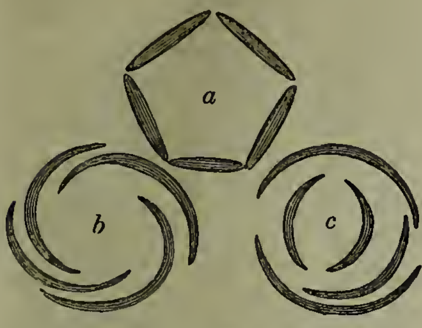
Imbricated, when the pieces are placed in part externally, and in part internally, so that the latter are covered over by the former, as in the calyx of Hypericum (*fig.* 46, *c*).

Twisted or *contorted*, when each part is turned slightly on its own axis, so that by one of its edges it covers its neighbour, while it is, in like manner, itself covered by the piece which is next it, as in the corolla of a Mallow (*fig.* 46, *b*).

If the pieces of the floral envelopes are all distinct, this fact is expressed by prefixing the word *poly* (many) to the part which is spoken of, as *poly-*

sepalous, if the calyx consists of several pieces or *sepals;* and *polypetalous*, if the corolla consists of several *petals*.

Fig. 46.



But if the pieces grow together by their edges and form a tube or cup, we then say *monosepalous* or *monopetalous*, that is, *one-sepaled* or *one-petaled;* by which is to be understood that they are all grown into one, and not that such a tube or cup is only one piece notched at its edge. The Greek privative *a* is also employed to designate their absence, as *asepalous*, or *apetalous*.

Sometimes the upper part of the floral envelopes grows into a solid lid, and separates from the lower, falling off like a cap; this happens to the calyx of Eucalyptus (*fig*. 47, *a*), and to the corolla of Eudesmia (*fig*. 47, *b*).

Fig. 47.

Calyx.—When the calyx is distinguishable from the corolla, it is commonly known by being smaller, greener, and more leaf-like, or more permanent. But such characters will not always indicate it, for we find it more richly coloured and larger than the corolla in the Fuchsia, and more deciduous in the Poppy. In fact, there seem no means of defining the calyx better, than as the most exterior whorl of the floral envelopes; and consequently the name is so applied, whatever the colour, size, or other characters of the exterior whorl may be; and hence if there is only one whorl, that one is calyx. Care, however, must be taken, when the sepals and petals grow together into a tube, that such a circumstance does not prevent our perceiving the presence of two whorls, as in the Crocus, in which a careful examination will show that there are really two whorls, each consisting of three pieces, one on the outside of the other, and consequently that both calyx and corolla are present.

The calyx frequently drops off when the flowering is over, but sometimes it continues to grow for a long time afterwards. Thus in the Gaultheria and the Strawberry-blite, it becomes red and succulent; in Christ's thorn (Paliurus australis), it expands into a broad thin woody rim; and in the black varnish tree of Burma (Melanorhæa usitatissima), it grows from little green scales into as many large, leafy, veiny, red parts, looking like a corolla surrounding the fruit.

Not only do the sepals grow together and form a tube or cup, but they sometimes grow to the outside of the ovary, so as to become quite incorporated with it, as in the Apple. When this happens, the calyx is called *superior* (*fig*. 48, *a b*), for it looks as if it actually grew upon the ovary; while, on the other hand, it is called *inferior* (*fig*. 48, *c d e*) in its ordinary position, as in the Cherry. The French, with more reason, say it is *free* in the latter case, and *adherent* in the former; but the first-mentioned terms, although not to be defended, are in most common use.

Fig. 48.

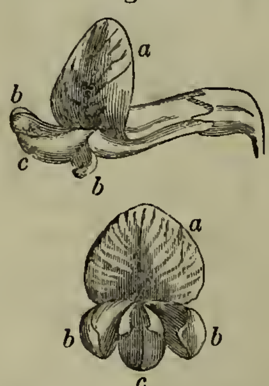
Corolla.—This part, which, it will be seen from what has lately been said, is only to be known with certainty from the calyx by its being placed between that part and the stamens, is often, nevertheless, the most conspicuous part of the plant, because the gay colours and the fragrant odours of flowers are generally resident in it.

The pieces, or *petals*, of which the

corolla consists, are sometimes so much narrowed towards the base as to be separable into two parts, just as a leaf may be separated into stalk and blade; in that case the stalk part of the petal is called the *unguis* or *claw*, and the blade has the name of *limb*. It is probably by petals of this sort that monopetalous corollas with long tubes are formed, the border consisting of the limbs, the petals and the tube of their claws in a state of adhesion. The orifice of such a tube is called the *throat* or *faux*. The petals alternate regularly with the sepals, and are usually either equal to them in number, or twice as numerous; but in consequence of the irregular way in which the petals and sepals respectively cohere, this cannot always be very well made out. For instance, in the garden Sage, the calyx has apparently two lips or parts, while the corolla has four; but if the former be attentively examined, its upper lip will be found to consist of three, and its lower of two sepals; while in the corolla the upper lip consists of two petals, and the lower of three, adhering unequally and irregularly. Hence the calyx and the corolla of that plant really consist each of five pieces.

The pieces of a corolla are not unfrequently extremely unequal in size, and irregular in form and direction. It is, however, only in a *papilionaceous* corolla that special names are given to the parts. A corolla of this description is found in the Pea, and consists of, 1st, a broad roundish petal, which stands erect from the others (the *vexillum* or *standard*) (*fig.* 49, *a*); 2nd, of

Fig. 49.



two oblong, parallel, slightly convex petals (the *alæ* or *wings*) (*b*), which conceal, 3rd, the *keel* or *carina* (*c*), which consists of two petals sticking together by their front edges.

Sometimes petals have membranous scales growing from their upper surface, as in the Catchfly (Silene); they are in that case said to be *crowned* or *coronate*, and their appendage is named the *corona*. Parts of this nature are not to be confounded with abortions of the stamens, which are extremely common, and very like them, but of an essentially different nature. Abortive stamens are processes of a distinctly fleshy nature, and usually traversed by at least one minute parcel of vessels; mere processes of the corolla, on the contrary, are nothing but membranous expansions of cuticle, without any distinct trace of vessels.

The office of the floral envelopes is in part to act as a protection to the fertilizing and fructifying organs when they are young, and to guard them from sudden variations in temperature, by the thin layers of air which they cause to be interposed between those parts and the atmosphere; but it is also probable, that when green, they act like leaves as elaborators of food upon which the organs of reproduction may be nourished, and that when coloured the corresponding change in their chemical operation still further contributes in a special manner to the same end by the conversion of crude fæcula secreted at their bases into sugar, the superfluous parts of which flow off in the form of the honey, which many flowers are so well known to yield in considerable abundance. For the detailed evidence upon which this is supposed to be proved, the reader is referred to Physiology.

Chapter XVII.

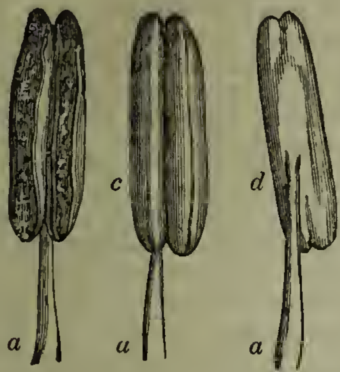
Of the Stamens, or Fertilizing System.

The fertilizing system, called by many modern writers the *andræceum*, consists of the organs which are arranged between the floral envelopes and the pistil, or fructifying system. Such organs are technically named *stamens*, and usually consist of two parts, viz., a slender white stalk or *filament*, and a yellow or brown head or *anther*. Of these the essential part is the anther, the filament being of no more importance to the latter than the foot-stalk to the leaf.

An accurate idea of the normal state

of the filament and anther may be taken from the Lily. In that plant the filament is a long, fleshy, awl-shaped, greenish-white body (*fig.* 50, *a*), the

Fig. 50.



surface of which is furnished with stomates, and the centre with a bundle of vessels. On its point is placed the anther (*b c d*), which is a narrow, reddish-brown body, having a deep furrow passing down its longer diameter, and being thus separated into two parallel lobes. The part that unites the lobes is a continuation of the filament, and is called the *connective*. Each lobe, before it opens, is marked in front by a shallow furrow which passes from end to end of the lobe, dividing it into two somewhat equal parts (*c*). In course of time the sides of the lobe contract and separate at the last-mentioned furrow, which consequently opens (*b*), and allows a brownish-orange powder, named *pollen*, to fall out; the two sides of the lobe when they thus separate are called *valves*, and the furrow itself the *suture* or *line of dehiscence*. The anther of a Lily, therefore, consists of two parallel lobes, united by a connective, each formed of two valves opening by a longitudinal suture and discharging pollen. This may be considered typical of all filaments and of all anthers. Both these parts are, however, subject to numerous important modifications.

The filament owes the chief differences in its appearance to *flattening*, *distension*, or *contraction*. When exceedingly flattened it becomes so like a petal that it can only be distinguished from that part by its bearing an anther (*fig.* 51, *a c h*); this happens in the Indian shot (Canna), and in a less degree in the white Water-lily (Nymphæa). Distension acts in the most remarkable manner at the base, where it causes the filament to assume the appearance of a fleshy scale (*b*), as in Zygophyllum and Campanula. In a state of contraction it becomes a mere thread, as in Grasses; and even disappears altogether as in a great variety of plants. It is generally smooth, but in the common Spiderwort (Tradescantia) it is covered all over in the middle with long, necklace-shaped hairs, arranged in a dense tuft; in this state it is called *stupose* (*fig.* 51, *d e*).

Fig. 51.

The anther is much more variable in its appearance than the filament, and from causes of a different nature. In cases where the lobes unite so as to be undistinguishable, the anther may become absolutely one-celled (*fig.* 52, *a*), as in Epacris, or it may be two-celled, without any external indication of that fact, as in Arum and all its allies; or finally, the sutures may grow by their edges to the inside back of the cells, and so convert a two-celled anther into one with four cells, as in the Ash. But if one of the lobes of the anther is undeveloped, or abortive, it may become one-celled from that cause alone, as in the Indian shot (*fig.* 51, *a*).

On the other hand, a distension of the connective will produce very singular anomalies. Suppose that part to spread right and left without lengthening, as in the Monarda, the lobes will be at right angles with each other, instead of being parallel; and if they should grow together at their points (*fig.* 52, *n*), the anther itself will become one-celled from this cause, in addition to those before mentioned, as actually happens in the Mallow. Let

the connective grow much beyond the lobes without widening, and the horns of the anther of some Orchideous plants, the membranous crest of the Violet, or the fleshy crest of the Ginger tribe (*fig.* 51, *h*) (Scitamineæ), will be the result. A third modification of the appearance of this organ may arise from the connective growing much more on one side than the other, having no anther on the side of excessive growth, and also taking on that side a direction different from what is habitual to it in other plants. This is particularly remarkable in the Sage genus, the anthers of which are one-celled, and look as if they rode upon a two-legged body (the connective), which is itself astride of a slender fleshy process (the filament). See *fig.* 52, *f.*

Fig. 52.

Occasionally the lobes of the anther, instead of being parallel with one another, and at the same time straight, retain their parallelism, but fold and double up upon themselves; and this produces the sinuous appearance in the anthers of a Gourd (*fig.* 52, *r*). Or, finally, they may give birth to processes of different shapes, which give them a horned or spurred, or crested appearance, as in many plants of the Heath tribe (*e d*).

The manner in which the anther bursts, so as to allow the pollen to escape, is usually by an opening all along each suture, or line of dehiscence; but if that line will only open at one point (*fig.* 52, *d p m l*), as in the Potato, the appearance of a pore is the result; and such anthers are termed porous. But in the Barberry, and the Sweet bay tree (Laurus nobilis), the anthers are said to open by reflexed valves (*fig.* 52, *o q*); in those plants the whole face of each valve of the anther comes off from the lobes except at the apex, where it continues to adhere firmly, and there contracting, it curls up, and allows the pollen to drop out. In such plants the anther, in its young state, is exactly like one which finally opens longitudinally; but it would seem that eventually it is unable to expel the pollen by the usual suture, which will not give way to the force exerted by the pollen grains from within. It is, however, indispensable that something should give way, and, consequently, the face of the anther separates all round, and having separated, curls up in consequence of the contraction of all its parts.

In Mistletoe, the mode in which the anther opens is altogether anomalous: bursting when ripe by a number of holes which are scattered over its whole surface (*fig.* 52, *s*).

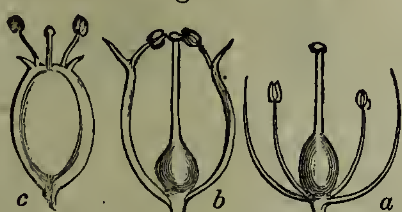
In their number the stamens follow no constant rule; for although it is certain, as will be hereafter proved, that their most normal number is, in all cases, the same as that of the segments of the calyx or of the corolla, yet, what with multiplication, abortion, and transformation, they are very often extremely different from the quantity of the floral envelopes. The only rule that can be said to be fixed concerning them is, that if they are fewer than the segments of the calyx or corolla taken separately, the difference is owing to a part of them being abortive or transformed; and if there is more than the segments, they are always in that case some multiple of the number of the latter, unless in consequence again of transformation or multiplication. For illustration of this position the reader is referred to Chapter XXV.

The stamens sometimes grow to one another, or to neighbouring parts, by both which circumstances their true

character is more or less masked. In the Mallow, the filaments of a great many stamens grow together into a tube, and are called *monadelphous;* in the Pea, they grow into two unequal parcels, and are *diadelphous;* in the Tutsan (Hypericum), they grow into several parcels, and are called *poly-adelphous.* In common Groundsel (Senecio vulgaris), Lobelia, and many others, the anthers unite to each other by their edges, and are called *syngenesious.* And in Birthwort (Aristolochia), and the Orchis tribe, anthers, filaments, styles, and stigmas become all consolidated and confounded in one central body, named the *column;* plants with this remarkable structure are said to be *gynandrous.*

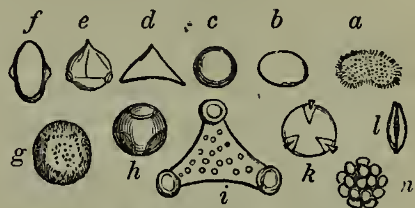
In addition to adhesions of this sort, there is another class, of which great use is made in systematic botany. In the normal state of a flower, the stamens arise from the angle formed between the base of the calyx or corolla, and the ovary (*fig.* 53, *a*), and are then said to be *hypogynous;* but in the Plum, the stamens grow by their lower end to the side of the tube of the calyx, only separating from it at the line where the petals arise; they are then called *perigynous* (*b*); and in the Myrtle they not only grow thus to the side of the tube of the calyx, but also to the face of the ovary, and join those two parts into one body: from this cause they look as if they grew upon the top of the ovary, and are said to be *epigynous* (*c*).

Fig. 53.



Pollen.—The pollen (*fig.* 54), which to the naked eye looks like very fine dust, is the most curious and most varied part of vegetation. It consists of a prodigious multitude of little grains, whose figure is generally uniform in the same species, but which have some hundred modifications of form in different species, and which vary in size from the $\frac{1}{30}$th to the $\frac{1}{240}$th of a line in diameter. Most of their forms are reducible to the spheroidal and the triangular, but some are oval, as in the majority of Umbelliferous plants (*fig.* 54, *l*), and others polyhedral, as in some Compound flowers. The grains of pollen are most commonly single, but in many Acacias they are clustered in little round balls (*m*), and in Orchideous plants in threes or fours; their surface is for the most part smooth, but many are hairy or bristly, or covered with little tubercles symmetrically arranged. Occasionally there are circular spaces upon the surface which open like little lids when the contents of the pollen-grain are discharged, as in the Passion-flower (*h*).

Fig. 54.



In some species, such as many of the Orchis tribe, and all Asclepiadeous plants, the pollen falls in mass from out of the anther, the grains adhering to one another in different ways. In the Orchis, they are collected into wedges, which stick to a central elastic thread; in Neottia they are joined imperfectly in threes and fours, and united by an elastic web; and in Malaxis they form a solid, homogeneous substance, of a waxy texture. In Asclepiadeous plants they are collected within a bag which appears to be the lining of the anther separated from the valves.

The shell of the pollen-grain seems from the best modern authorities to consist of two layers, the external thick, fleshy, and cellular, the internal very thin, membranous, and extensible. Of these the external has often apertures at its angles through which the inner membrane projects in a slight degree, from which cause the angles appear semi-transparent when the pollen is magnified and viewed in water by transmitted light. In those cases in which only one membrane is present, it is said that it is the interior, and that in such instances no trace of aperture is visible.

The structure of the pollen, in consequence of the excessive minuteness of the parts, is not to be seen without much difficulty; but Dr. Fritzsche, a young Prussian botanist, has lately

shown that it may be observed with greater facility than was before supposed by examining the grains in a liquid composed of two parts of concentrated sulphuric acid and three parts of water. By this means, the external coating of the pollen is rendered transparent, the matter within it is coagulated, and partially forced out through the apertures, in the form of long intestine-like sacs, which are called *pollen-tubes*. This phenomenon occurs spontaneously when the grains of pollen have fallen for a few hours upon the stigma, and it is through such intestine-like sacs that the fertilizing matter is ejected from the pollen-grain into the conducting portion of the tissue of the stigma.

The matter which is ejected appears, under a microscope of low power, to be merely a turbid fluid, denser than the water into which it is discharged; upon magnifying glasses of sufficient power being applied, the turbid fluid is found to consist of oblong particles about the $\frac{1}{5000}$th of an inch in diameter, and spheroidal molecules varying in size from the $\frac{1}{15000}$th to the $\frac{1}{25000}$th of an inch in diameter, according to the computation of Mr. Dollond. These, when floating in water, are in active motion, each revolving upon its own axis, and the larger kind having often a sort of spasmodic contraction of the side. It is a general belief that these larger particles are the rudiments of embryos, and that the effect of fertilization is to convey one of them into the ovule; but there is not, and probably from the nature of things never can be, any proof of the correctness of this opinion. Fritzsche, however, asserts that the particles are nothing but grains of amylaceous matter, or globules of oil, and denies their having anything to do with fertilization. It may, however, be observed, that supposing them to be grains of amylaceous matter, yet as they are of definite and regular form, and have a specific motion, it is by no means improbable that nature may have destined them to perform the important action that is ascribed to them. Amylaceous matter, in a dead state, ought not to be confounded with the same substance imbued with the living principle, which takes it beyond the ordinary laws of chemical action, and gives it powers of a special nature. Nor is it to be admitted that the particles of the pollen-fluid cannot be destined to act as a fertilizing power, because grains apparently of the like nature taken from parts having no fertilizing action, will move, as it were, spontaneously when suspended in water; as, for instance, the particles of which the ovary of wheat consists. For in bodies so infinitely small as those in question, nothing is revealed by the microscope beyond their external form, and no one can say that bodies which seem under the microscope to be identical, would not, in fact, be found to be entirely different if it were possible to perceive their structure more distinctly.

Chapter XVIII.

Of the Pistil, or Fructifying System.

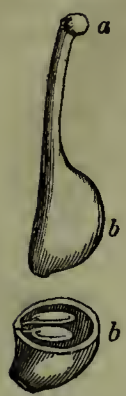
The fructifying system, or *gynæceum*, occupies the centre of a flower, and is the part round which all the other parts are arranged; it is generally called the pistil.

The pistil consists of certain component parts called *carpels*, which are either distinct from each other, as in the Strawberry (*fig.* 55, *a*), or all grown together into one body, as in the Rhododendron (*fig.* 55, *b*); or if the pistil consists of but one carpel as in the Cherry, then the terms pistil and carpel have the same meaning.

Fig. 55.

A carpel consists of *ovary* and *ovules*, *style* and *stigma* (*fig.* 56). The ovary is the lower portion (*fig.* 56, *b*), which is hollow, rounded at the back next the calyx, and sharp at the opposite edge, within which is a double line corresponding with an external suture, and called the *placenta*. The ovary tapers upwards into a slender horn or thread, called the *style*, and on the point of that organ there is a humid space, destitute of cuticle, and usually a little, sometimes very much, distended, which is the *stigma* (*a*). Of these parts the ovary and stigma are present in all carpels, but the style is not more essential than the footstalk to the leaf.

Fig. 56.



The part from which the ovules originate, consisting of an excrescence, more or less considerable, of the united edges of the carpel, is what has been called the *placenta*. Sometimes it bears but a single ovule, more frequently two, and generally a greater number; in many cases it is scarcely visible except in consequence of the ovules growing out of it, but most commonly it has distinctly a fungous appearance, and very often is of considerable size, as in the Primrose and the Lychnis dioica. We shall see, as we proceed, that it is an organ of great importance.

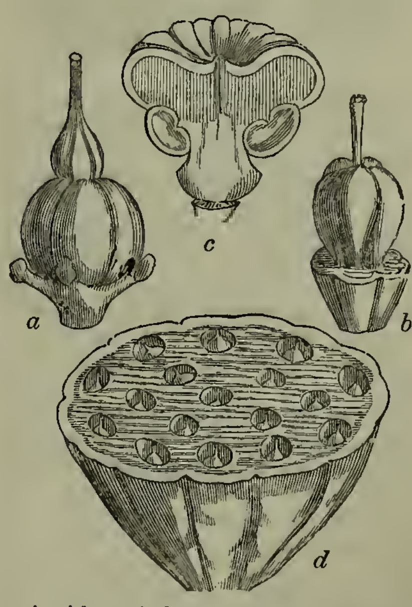
All the principal modifications of pistil with which we are acquainted are produced by the various modes in which the carpels are joined or arranged, or by the state of the growing point round which they are placed.

When one carpel only is present, as in the cherry, the pistil is *simple;* but if more than one carpel is found in the same flower, it is *compound.* Supposing its constituent carpels to be separate from one another either entirely, or to a considerable degree, the pistil is called *apocarpous* (*fig.* 55, *a*), as in the Crowfoot (Ranunculus), the Rose, the Aconite, &c.; but if the carpels grow completely together, the pistil is *syncarpous*, as in the Arbutus, the Lilac, the Chickweed, &c. (*fig.* 55, *b*).

In the disjoined state of the carpels, there are few states of the pistil that deserve to be pointed out, except such as result from an enlargement or hardening of the growing point round which the carpels are placed.

The nature of the growing point in a leaf-bud has been already explained; see page 19. In a flower-bud it has usually no power of extension; for the act of forming the floral organs seems in general to paralyze the central tissue, and to render it incapable of further development; and consequently the carpels are usually the absolute termination of the axis of growth. But in some cases, after the carpels are formed, a partial tendency to develop is manifest, and the central substance rises up between the carpels, disjoining them, and sometimes extending far beyond them (*fig.* 57, *c*). Thus in the Strawberry this power of extension produces a succulent receptacle, which bears the carpels scattered over its surface; in the Geranium it projects beyond the carpels, growing to their styles in the shape of a hardened beak; in the Rue it forms a central column, which is not very visible till the fruit is ripe; and finally in the Nelumbium (*fig.* 57, *d*) it rises up about the carpels, and forms a sort of hemispherical disk in which they are immersed. When it is succulent and belongs to a greater number of carpels than five, it is called *torus*, or receptacle; but when it has five carpels, or a smaller number, placed regularly round it, and finally separating from it, and from each other, when ripe, it is called a *gynobase* (*fig.* 57, *a b*).

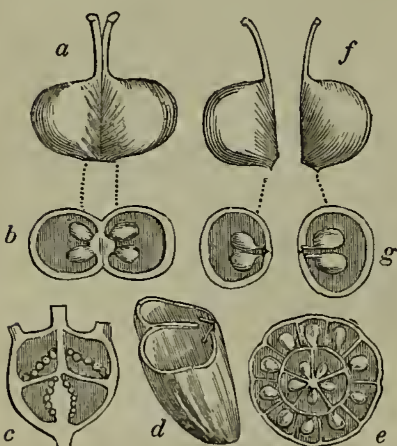
Fig. 57.



An idea of the manner in which the appearance of the pistil is modified by the number of carpels that form it by their union, will be best obtained by

first considering the effect of two being completely combined. Let *fig.* 58, *f*, represent two carpels placed opposite each other, but distinct, each having its own style and stigma; then the *fig. g* will represent the appearance of a transverse section of them, with the two placentas pointing towards each other. Also let *fig.* 58, *a*, represent a pistil formed of two carpels combined, and *b* the transverse section of the same. It will then be obvious that the style and stigma of *a*, although apparently simple, are, in fact, composed of two styles and two stigmata grown to each other throughout their whole length, and that the ovary of *a* is in like manner made up of two ovaries complete

Fig. 58.



in all their parts. It will further be apparent that the partition which divides the cavity of the ovary *b* into two equal parts, consists in part of the face of the right hand, and in part of that of the left hand carpel at *a* and *f*, and is consequently organically double, however simple it may appear to the eye to be. The placenta also at *b*, although seemingly simple, must in like manner be composed of the placentas of two carpels.

Now if we exchange a pistil formed of two carpels for one into the composition of which five enter upon a similar principle, we shall have an ovary with five cells, five dissepiments, and five placentas united into one in the centre.

If we consider the relation which these parts bear to each other, it will be apparent that as the dissepiments are formed by the sides of carpels, and as the stigmata are the termination of the backs of the latter, the stigmas must of necessity be placed in all cases of normal structure between the dissepiments, or alternate with them. Hence it is an axiom in structural botany that no partition in an ovary is a genuine dissepiment, unless it bears this relation to the stigmata, and that all others are spurious; and moreover, that all true dissepiments must radiate from a common centre in a direction parallel to the stalk of the ovary. So that such vertical partitions as are met with in the ovary of Amelanchier and Astragalus, proceeding from the back or front of the cell, opposite the stigma, or as occur horizontally in the fruit of Cathartocarpus fistula, are not called dissepiments, but have the technical name of *phragmata*.

The only exceptions that can possibly occur to this law of the relation borne by the dissepiments to the axis and to the stigmas, is in cases where more rows than one of carpels grow together. When this happens *upon the same plane*, the outer row grows by the placentiferous face of each carpel to the back of the carpels of the inner row, as at *fig.* 58, *e*, and then new dissepiments are produced *at right angles* with the common radiating ones. But if two rows, which arise from two different planes, adhere to each other, the position of the parts will become, as at *fig.* 58, *c*, so oblique, that genuine horizontal dissepiments will be the result. This has been shown by Dr. Lindley to be the explanation of the curious structure of the Pomegranate.

Although, from what precedes, it would seem to follow that all pistils consisting of more carpels than one grown together should contain cells separated by true dissepiments, yet this rule is sometimes deviated from in consequence of certain special modifications of the usual manner of growth. Suppose the constituent carpels of a syncarpous pistil not to be closed up at the edge which bears the placentæ, but to be partially opened, and yet to grow together where they touch; they would, in such a case, form what is called a one-celled pistil, with *parietal* placentæ (*fig.* 59, *a*), in which the sides of the carpels only project from the inside of the pistil into its cavity, without meeting in the centre: this happens in the Poppy, and many other plants. Or it may occur that a pistil, originally of the most normal structure, may assume an anomalous ap-

pearance after a certain period, in consequence of an inequality in the rate at which its different parts may grow. Thus, in what are called Caryophylleous plants, such as the Lychnis dioica, the Mouse-ear chickweed (Cerastium), &c., the pistil, when very young, has several cells, separated by complete dissepiments, and joining in the middle by their respective placentas. But after a time the dissepiments lose all power of growing, while the placentas expand, and the shell of the ovary increases steadily in dimension; in consequence of this the dissepiments are ruptured by the opposing strain of the placentas on the one hand, which will not separate, and of the shell of the ovary on the other, or, in other words, of the back of the carpels, which are compelled to spread away from the centre by the addition that is constantly making to their dimensions in every direction; the circumference of such a pistil is perpetually pulling against the centre, and as the dissepiments will neither grow nor stretch, they must necessarily be rent in twain (*fig.* 59, *b*). From this results—1. if the placentæ grew along the whole length of the inner edge of the carpels, a *free central placenta*, as in Lychnis (*fig.* 59, *b*); or 2. if they appeared only at the base of the inner edge of the carpels, a *free basal placenta*, as in the Tamarisk (*fig.* 59, *c*).

Fig. 59.

c b a

Instances of this kind serve to show the student of botany, that the most singular anomalies of structure are susceptible of easy explanation if attention is steadily fixed upon first principles; and that it is highly unphilosophical to suppose that the simplicity of design which is so generally manifested in the works of nature, is departed from in certain special cases, merely because we may be unable rightly to understand them without reflection.

There are few modifications of the *style* which are worth noticing, except such as are caused by its distension in one direction, when it becomes petal-like, or in all directions when it is club-shaped and massive. In the Iris is one of the most remarkable instances of its assuming the appearance of a petal; and Indian shot (Canna) affords another. In Asclepias, Stapelia, Tupistra, and others, it becomes succulent, and acquires a fungus-like appearance.

The *stigma* is subject to similar alterations, but in a much less degree, and it is probable that many anomalous forms referred by botanists to the stigma really belong to the style. Some of its most singular states are the following:—in Rhubarb (Rheum) it forms three flat orbicular disks, in Dock (Rumex) as many fringed round tassels, and in Grasses a tufted hairy body like the brushes with which holy water is scattered about in Catholic churches. In the Poppy the stigmas collect into a star-like body, crowning the top of the ovary; in the Heart's-ease it is a hollow globe with a small aperture on one side; in the Monkey flower (Mimulus) it consists of two membranous lips which have the power of contraction when irritated, and in Clarkia it consists of four broad white petal-like lobes. In Orchideous plants it is an oval humid space hollowed out of the face of the central column of those plants, and in general it has a surface which is covered with a clammy or gluey secretion; this is no doubt a provision for enabling it to retain the pollen grains when they fall upon it; when it has not such a contrivance, it is covered over with long finger-like processes, in which the pollen is entangled, as in Grasses, &c. There are, however, some plants in which the surface of the stigma is undistinguishable from that of the style, as in Birthwort (Aristolochia), Asclepiadeous plants, and Tupistra.

Generally the stigma is undivided, and consequently the number of stigmas indicates the number of carpels of which a syncarpous pistil consists. But this mark is not always to be trusted; for in most Euphorbiaceous plants the stigma of each carpel is divided into two deep lobes, and in Grasses, the pistil of which is perfectly simple, there are uniformly two stigmas some distance apart at the base. It is important that this should be well considered by those who are engaged in the study of vegetable structure; for it will sometimes offer an easy solution

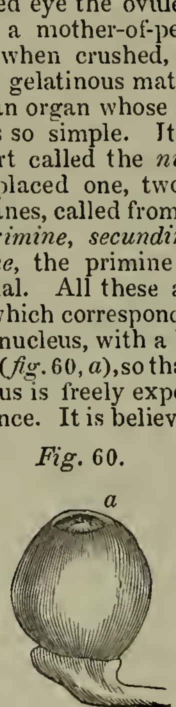
of what may at first appear a most difficult problem. For instance, Cruciferous plants have their stigmas apparently opposite the placentas; Dr. Lindley has attempted to explain this away by assuming that the structure of the pistil of such plants is in reality much more complicated than it seems to be; but Dr. Brown, on the contrary, finds a simpler and apparently a more probable explanation in the original two-lobed structure of the stigma of Cruciferæ.

Chapter XIX.

Of the Ovule.

To the naked eye the ovule is an oval grain with a mother-of-pearl colour, and seems, when crushed, to be simply a bag of gelatinous matter; but in reality it is an organ whose structure is by no means so simple. It consists of a central part called the *nucleus*, over which are placed one, two, three, or four membranes, called from their position the *primine*, *secundine*, *tercine*, and *quartine*, the primine being the most external. All these are pierced, at the part which corresponds with the point of the nucleus, with a hole called the *foramen* (*fig.* 60, *a*), so that the point of the nucleus is freely exposed to external influence. It is believed that the

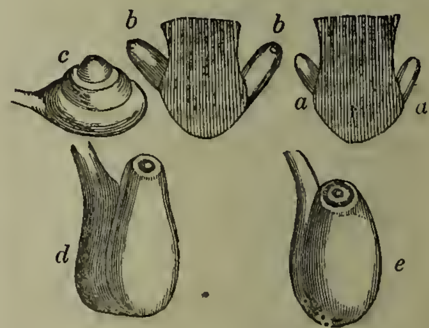
Fig. 60.



fertilizing influence of the pollen, of whatever nature it may be, is here introduced; for it is uniformly found that the rudiment of an embryo first appears at the point of the nucleus; and, in fact, the foramen of the ovule may be taken with perfect confidence as the situation of the future radicle of the embryo; a point of no inconsiderable importance in systematic botany. Although the ovule is in some cases furnished with the four integuments just mentioned, to which a fifth, the *quintine*, or immediate coat of the nucleus, has to be added, yet in the majority of cases the primine, secundine, and tercine are all that can be detected, and even one of these is absent in the Alder and its allies, whose ovules have only a primine and a coat to the nucleus. These facts have been elucidated chiefly by the careful investigations of Brown and Mirbel.

The situation of the foramen is always at a very early period of the growth of the ovule at the apex; and in many ovules it subsequently remains there; but in the majority of plants the ovule bends down upon itself, and gradually brings its apex down to its base, when the foramen becomes con-

Fig. 61.



tiguous to the point of insertion of the ovule. This is particularly well seen in the gourd tribe, whose changes from a very early state, when the ovule is a mere pulpy tubercle, to its perfect condition, are easily followed, and have been admirably illustrated by Mirbel. *Fig.* 61 represents this: *a a* are two very young ovules in their original state; *b b* are the same grown older, with the foramen just appearing; *c* is one of them with its three coats fully formed and half bent down upon itself; *d* shows the further change when the ovule has actually become inverted in consequence of the bending down being accomplished; and *e* represents the ovule in its perfect state, when ready to be fertilized.

It appears probable that the different stations of the foramen upon the surface of the ovule are closely connected with the peculiar manner in which, from the structure of other parts, the phenomenon of fertilization takes place in different species of plants

The position of the ovule, with regard to the ovary, is *erect* when it rises from the very base of the cavity; *ascending* when it originates a little above the base; *pendulous* when it hangs from

the very apex; *suspended* when it is hung up as it were from a little below the apex; and finally, *horizontal* or *peltate* when it is attached by its middle to the middle of the placenta.

Further, ovules are said to be *definite* when their number is uniform and easily counted; and *indefinite*, if their number is uncertain and too great to be correctly counted.

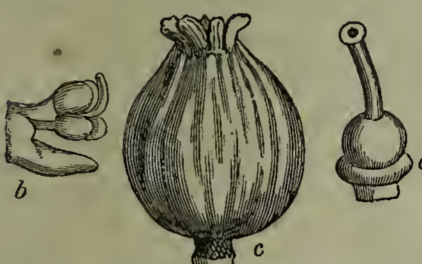
Chapter XX.

Of the Disk.

This name is given to a body which arises from the base of the ovary in the form of a ring, or of scales, or glands, or of a sort of cup. It is almost always fleshy, and seems in most cases to secrete honey.

In the Orange, it is a yellowish fleshy ring (*fig.* 62, *a*); in the alpine Scull-cap (Scutellaria) (*fig.* 62, *b*), it is a thick scale placed on one side of the ovary; in the Mignionette (Reseda), it is a broad hairy plate, out of which the ovary arises; in Grasses it is two minute hypogynous scales; in the tree Pæony it is a purple cup, which covers the pistil all over except the stigmas (*fig.* 62, *c*); and in the Cherry it forms a thick shining lining to the tube of the calyx. Besides which, it is found under other forms.

Fig. 62.



It is probable that this organ is, in all cases, a rudimentary state of some undeveloped stamens; and that it is altogether of a different nature from the torus (see p. 43) with which it is generally confounded. That such is its real nature, seems to be proved by these circumstances: that in some Meliaceous plants, such as Turræa pinnata, it is exactly like an external cup, which bears the stamens, and is manifestly produced by the juncture of their filaments; that in Scitamineous plants its parts occupy the place of certain stamens which are not to be found in the place where they ought to be stationed in a case of regular structure; and that in the tree Pæony it has actually been seen with an anther growing upon it.

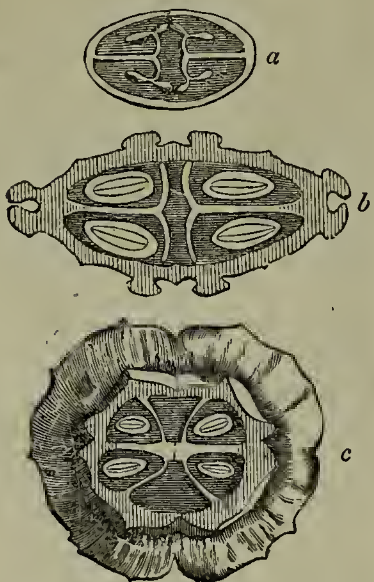
Chapter XXI.

Of the Fruit.

The fruit of a plant is the fertilized ovary arrived at maturity, and consequently both organs must have the same structure in all their more essential points; for the plan upon which the ovary is to be constructed is finally determined at the period when fertilization takes place, and all that happens to it afterwards is an enlargement and hardening or softening of its parts, together with, in some instances, a suppression of one portion by the excessive growth of the adjacent portions; or in other instances by the addition of something which only existed in a rudimentary state at the period of fertilization. A few instances will serve to show how this happens. In the Oak the ovary has three cells, in each of which there are two ovules; in the acorn, which is the fruit of the oak, there is only one seed and one cell: here two cells and five ovules are destroyed by the exclusive growth of one ovule. In the ovary of the Sweet chestnut (Castanea) there are seven cells with two ovules in each; the ripe fruit consists of but one cell and one seed, so that in this instance no fewer than six cells and thirteen ovules are suppressed, in order to enable a single ovule to grow and be matured. Another common instance in which a variation exists between the ovary and the mature fruit, but from a different cause, occurs in the genus Astragalus, of which the ovary is absolutely one-celled, but the fruit two-celled; an extension of the back of the cell, subsequent to fertilization, projecting forward into the cavity, and touching the placenta, is the cause of this. But one of the most remarkable deviations from original structure has been described in the *Botanical Register*, t. 934, in the fruit of a genus called Martynia. The author says that its fruit had been always described as four-celled, but that upon a careful examination of the ovary, it will be found that the fruit, in that stage (*fig.* 63, *a*), is neither four-celled, nor even two-celled, but consists of only one cell, traversed by two projecting parietal placentæ, each of which is two-lobed, the lobes dividing at right angles from their point of separation, and

bearing on their edges a few horizontal ovules, of which part project into the open centre of the ovary, and the others

Fig. 63.



into the cavity between the placenta, and the lining of the ovary. Now, the fruit (*fig.* 63, *b*) differs from the ovary in no essential point of structure; but the following changes take place: the shell of the ovary and the placentas become hard and woody; the inner faces of the latter become pressed together, so as to destroy the ovules which were placed between them, and to exhibit the appearance of a dissepiment of two plates; and the remaining ovules become pendulous and reduced in number, mature in the form of large wingless seeds between the inner edge of the lateral lobes of the placenta and the shell of the fruit. To this we may add that in a genus called Pretrea, nearly related to Martynia, the lateral lobes of the ovary actually grow to the shell where they touch it (*fig.* 63, *c*), and to each other in the middle, so that an ovary of one cell becomes changed by adhesions into a fruit of six cells. These, and there are multitudes of similar instances, ought to teach the young botanist never to hope to understand the true structure of the fruit of a plant, without having recourse to the anatomy of its ovary; for plants are perpetually in a state of masquerade, which, to the eyes of those who do not know the value of a rigid observance of first principles, must be impenetrable.

Having premised thus much concerning the general nature of the transitions from ovary to fruit, we proceed next to some observations upon the normal condition of the latter organ.

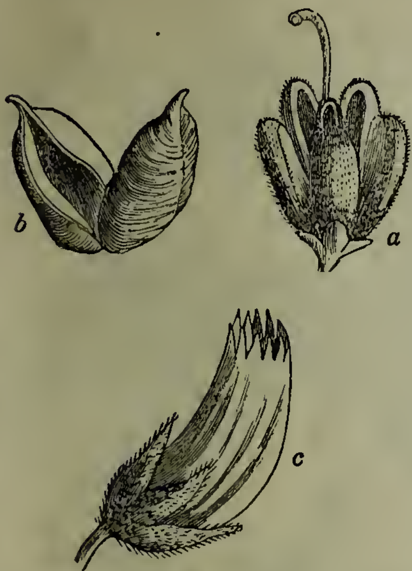
Its shell is what botanists call the *pericarp;* this part is usually homogeneous, but in some plants is not so. In the Peach, for example, the outside is a thin membrane, which may be easily peeled off: it is called the *epicarp;* then comes a quantity of sweet pulpy matter which we eat: that is the *sarcocarp;* and finally there is a hard bony wrinkled part called the *stone* by the vulgar, and the *endocarp* or *putamen* by the botanist. These distinctions are important in describing plants, because descriptions often require that not only all parts, but all modifications of parts, should be indicated by special names.

Some fruits are always closed up to the latest hour of their existence, as the cocoa-nut; others have the property of bursting into separate pieces or *valves* when ripe, as the lilac. This act of bursting is called *dehiscence*, and its varieties are often of material importance in distinguishing plants from each other. We must therefore state what are the typical forms of dehiscence. But for this purpose we must revert to the original structure of the pistil.

A simple pistil is composed of a single carpel, which has a *ventral suture*, to which the placenta adheres, and a *dorsal suture*, which has no placenta. All fruits are composed either of one or of many carpels. If of many carpels, the dissepiments are formed by their union; if of one carpel, there are necessarily no true dissepiments. Suppose that when a ripe fruit dehisces, its carpels all separate from each other, as in the Rhododendron (*fig.* 64, *a*), then the dehiscence is called *septicidal*, and the fruit is resolved into its original elements; but if the carpels refuse to separate and give way only by their dorsal suture (*fig.* 64, *b*), then the dehiscence becomes *loculicidal*, as in the Lilac. These two cases are the most common, and the only ones which are worth naming, as instances of a regular manner of dehiscing; and almost all others are reducible to such types. When, for example, a fruit is said to burst by valves at its point (*fig.* 64, *c*), as in the Mouse-ear chickweed (Cerastium), a partial separation of the carpels takes place both at their dorsal sutures and between

each other, just at the end of the fruit; and in the Palma Christi (Ricinus), and many other plants, a sort of compound bursting occurs; first of all, the carpels separate from each other, and septi-

Fig. 64.



cidal dehiscence is the result; then each carpel splits by its two sutures: this is loculicidal opening; and finally, the shell divides into two layers (the sarcocarp and endocarp), which contract and separate from each other with some force

There are, however, some irregular forms, which are too curious to be passed by in silence, as they are not reducible to either or any of the two foregoing types. The Poppy (*fig.* 65, *d*)

Fig. 65.

discharges its seeds by a number of little openings which lie below the rim produced by its broad peltate stigmas; the Snapdragon (Antirrhinum) (*fig.* 65, *a*) has similar openings near the apex of its fruit; and the Blue-bells (Campanula) burst by ragged holes at the bottom of their capsule (*fig.* 65, *c*, &c.). The Spirting cucumber (Momordica elaterium) discharges its slimy pulp and seeds by ejecting them violently through the place where the fruit and the peduncle are joined, forcing out the peduncle like a plug from a barrel of fermenting liquor. The Primrose, and many others, bear fruit which opens by a transverse separation of the shell into two parts (*fig.* 65, *b*), the upper looking like a cap to the under; and the Bird's-foot trefoil (Ornithopus) has pods which break across into a number of joints. Finally, in most Cruciferous plants the valves of the fruit drop off a *frame* (*replum*), to which the seeds adhere, and which seems formed by a junction of the sutures.

In order to avoid circumlocution, the numerous varieties which occur among fruits have been classified by botanists, and names given to the most important of their modifications. By some writers this has been carried to a great extent; but by others the number of essentially distinct forms has been much circumscribed. Although for many purposes, especially for arranging a carpological collection, the more exact definitions of the former deserve to be adhered to, and consequently their nomenclature adopted; yet it must be admitted, that for the common purposes of descriptive botany, a very small number of terms is sufficient. No others will therefore be admitted into this sketch than such as are of every-day occurrence in the writings of botanists.

The *follicle* (*fig.* 66, *d*) may be considered as a carpel in its ripe state, opening by its ventral suture only, and consequently to be typical of all modifications of fruit, as the carpel itself is of all modifications of pistil. Instances of a solitary follicle are found in the Larkspur (Delphinium), and of several in the same flower in the Pæony, the Star anise (Illicium) (*fig.* 66, *c g*), and many others.

From the latter, botanists distinguish the *legume* (*fig.* 66, *f*), which is, however, hardly susceptible of a definition, so various are the forms under which it occurs. Its most genuine state is as we find it in the Pea where it is a

follicle opening by both dorsal and ventral sutures into two valves. But it is often incapable of opening, and then is only to be known by the distinct double suture which runs round it. In this state it is sometimes divided into a great number of cells, each containing one seed, and formed by hori-

Fig. 66

zontal partitions arising from the lining of the shell (*fig.* 66, *l*), as in Tetragonolobus and the Carob tree (Ceratonia); or it may be precisely like a common legume, except that it does not open; or it may be reduced to a single seed, as in Clover, Psoralea, &c. (*fig.* 66, *k*). But its most singular appearances take place when the shell contracts round the seeds, so as to look as if it consisted of a number of distinct joints; in the Sawpod (Biserrula) (*fig.* 66, *i*) it is compressed from the back to the front, and is deeply and regularly scalloped at each edge; in Horseshoewort (Hippocrepis comosa) (*fig.* 66, *h*) it is compressed laterally, and one side only is scalloped; in the French honeysuckle (Hedysarum coronarium) (*fig.* 66, *a*) it is simply contracted, and eventually falls into pieces, each of which contains a seed; in the Caterpillar plant (Scorpiurus) it is rolled up upon itself, and covered with tubercles (*fig.* 66, *b*); and finally, in the Snail-plants (various species of Medicago), the convolutions are extremely like those of some univalve shells (*fig.* 66, *e*). Such legumes as separate transversely into distinct pieces are sometimes called *lomenta*, or *lomentaceous*

The *achenium*, or grain (*fig.* 67, *b*), is a carpel which is one-seeded, does not open when ripe, and has no suture at all. It is what the old botanists called a naked seed, because it resembles a seed in size and texture. Instances of it occur in the Strawberry, the Crowfoot, and the Fig, in which what are popularly called the seeds are the *achenia*. Sometimes this kind of fruit is terminated by a kind of plume (*fig.* 67, *a*), as in Virgin's bower (Clematis), which is the hardened style covered over with long feathery hairs; or it is crowned by a number of scales or hairs called *pappus*, placed in a ring at its summit, as in Compound flowers (*fig.* 67, *c d*). Two achenia combined form the fruit of an Umbelliferous (*fig.* 67, *g*) plant, and two or four, united at their bases only (*fig.* 67, *e*), that of a Boragineous one.

A *cariopsis* is an achenium with a thin shell, which grows so close to the skin of the seed as to be inseparable and undistinguishable; such is the

fruit of Wheat, Maize, and other kinds of corn.

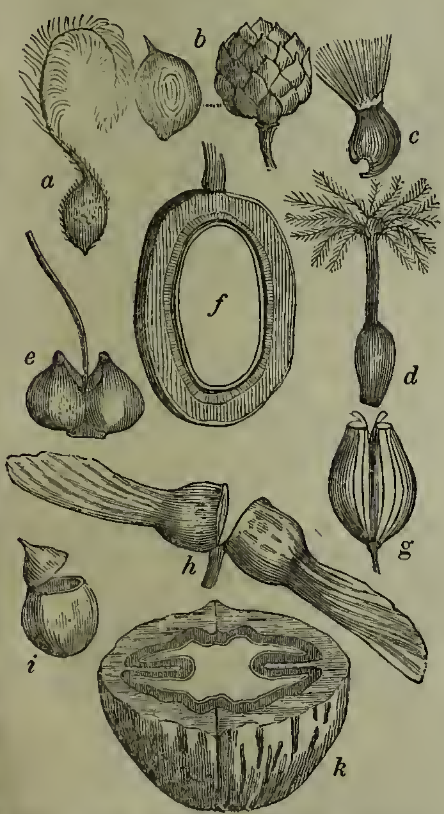
A *utricle* is a cariopsis with a thin loose shell; it would be an achenium if the shell were hard; it occurs in Goosefoot (Chenopodium), and often divides transversely (*fig.* 67, *i*).

A *nut* is an achenium in every thing, except that it results from a compound pistil, and is really composed of several carpels, although all of them may be abortive except one. The Hazel-nut, the Chestnut, the Acorn, are familiar instances of this.

The *key* (Samara) is either an achenium, or a nut with the summit expanded into a wing, as in the Ash and the Sycamore (*fig.* 67, *a*).

The *drupe* is an achenium with the shell separable into two layers, of which the inner is hard and bony, forming a *stone* or *endocarp*, and the other soft and juicy, forming a flesh. The fruits of the Peach, the Plum, the Cherry, are drupes (*fig.* 67, *f*).

Fig. 67.



The walnut is a drupe, the endocarp of which separates into two valves, each of which has an imperfect spurious dissepiment projecting from the back, and cutting the seed into deep lobes (*fig.* 67, *k*).

The *berry* (bacca) is composed of several carpels, which, when ripe, are a mere mass of pulp, in which the seeds lie buried, as the Grape and the Gooseberry.

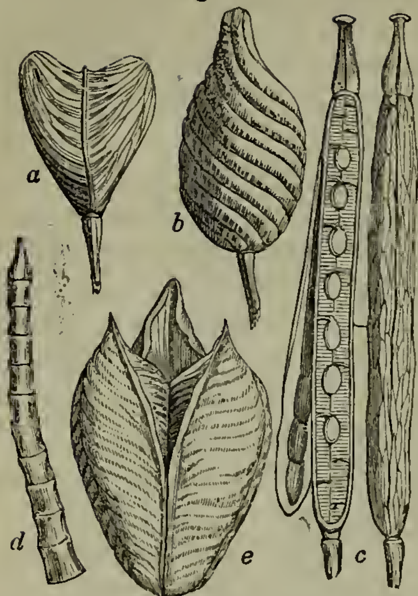
The *gourd* (pepo) is a berry with a hard rind, like a Melon.

The *pome* is a sort of fleshy berry, in which the inside of the cells is dry, so that the seeds do not lie in pulp; it is composed of a few carpels surrounded by a fleshy calyx, to which they grow, and may either have a thin and papery, or a thick and bony lining to its cells. The former, which occurs in the Apple, may be considered as a combination of fleshy follicles with a fleshy calyx; the latter, which we find in the Medlar, as a union of drupes to a fleshy calyx.

The *siliqua* (*fig.* 68, *c*) is a dry fruit, with two valves that separate from a frame to which the seeds are attached: in the Cabbage it is long and narrow; in the Shepherd's purse (Capsella), it is short and broad (*fig.* 68, *a*); the latter is called a *silicle;* in Sea-kale, the valves do not separate from the frame.

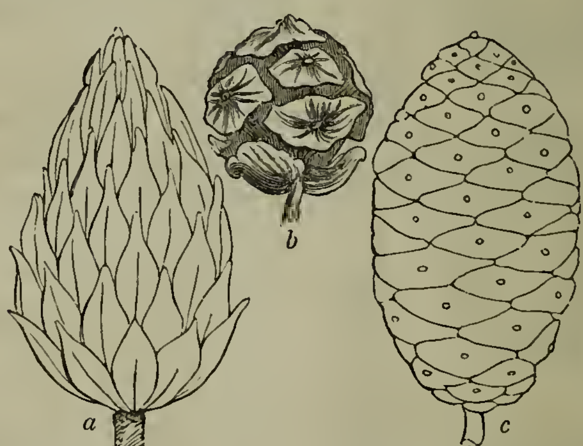
Finally, the *capsule* is a general term for all dry fruits which are composed of more carpels than one, and which dehisce when ripe; its application is even extended by combining it with modifying words; thus a *berried capsule* is a fruit having the ordinary structure of a capsule, with a soft, juicy shell, and not dehiscing; and so on. Taken in its most general sense, it is the most variable in appearance of all the organs of fructification. In Colchicum it consists of three follicles separating in a septicidal manner (*fig.* 68, *e*); this is a very common form of it. In Snapdragon, it consists of two cells opening at the summit by three pores (*fig.* 65). In the Sun-tree (Heliocarpus), it has two cells, opening in a loculicidal manner, and surrounded by long feathery processes which give it the appearance of a Catholic glory. In Hypecoum it is long, taper, curved, and separates into one-seeded joints like a lomentaceous legume (*fig.* 68, *d*), from which it is known by its seeds being attached to *both* sutures. In the Screw-fruits (Helicteres) it consists of five slender, narrow follicles, which are twisted together in a most remarkable manner (*fig.* 68, *b*).

Fig. 68.



Besides the foregoing, there are several fruits which are not produced by single flowers, but which are formed by the adhesion of a considerable number of flowers into a single mass. Such is the fir-cone, each of whose scales represents a single flower (*fig.* 69, *c*); the pine-apple, which consists of as many flowers as there are rhomboidal spaces upon its surface; and the mulberry, each of whose tubercles represents a single flower. These may either be all considered as varieties of the *strobilus* or cone; or with some others may be looked upon as forming a section in a methodical arrangement of fruits, in which latter case they would have several different names. It is more conformable to the plan of this treatise to take the first view of them; for an explanation of the other, the reader is referred to *Lindley's Introduction to Botany*, in which this subject is treated in detail. True cones (*fig.* 69, *b c*) must not be confounded with such aggregations of carpels as we find in the Magnolia (*fig.* 69, *a*), which are like cones in appearance, but which, in reality, are the result of the growth of one single pistil.

Fig. 69.



Chapter XXII.

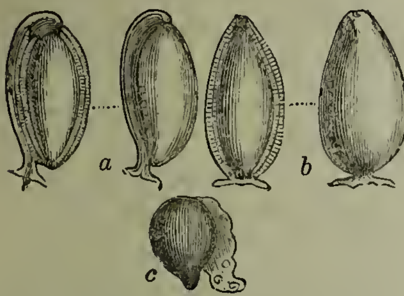
Of the Seed.

While changes are coming over the pistil subsequent to the discharge upon the stigma of the fertilizing principle of the pollen, the ovules are also undergoing a metamorphosis still more interesting and important. No sooner has the mysterious influence of the pollen been introduced into the ovule, than its foramen closes up, its integuments extend and harden, the pulpy substance within them consolidates, and in the midst of the latter, within the kernel, close to the foramen, there appears a minute, yellowish, opaque speck, which gradually enlarges and projects forwards into the centre of the kernel, absorbing the fluid that surrounds it, and, by degrees, assuming the appearance of an organized body which it ultimately becomes, in the form of an *embryo* plant.

The interior integument, within which, under the name of kernel, all this goes on, absorbs its food from the placenta either *directly* in those cases in which, the foramen being at the summit of the ovule, the base of the kernel is next the placenta (*fig.* 70, *b*), or indirectly by means of a cord of

vessels which expand at their termination in those cases in which the foramen is at the base of the ovule (*fig.* 70, *a*); in the latter case, the

Fig. 70.



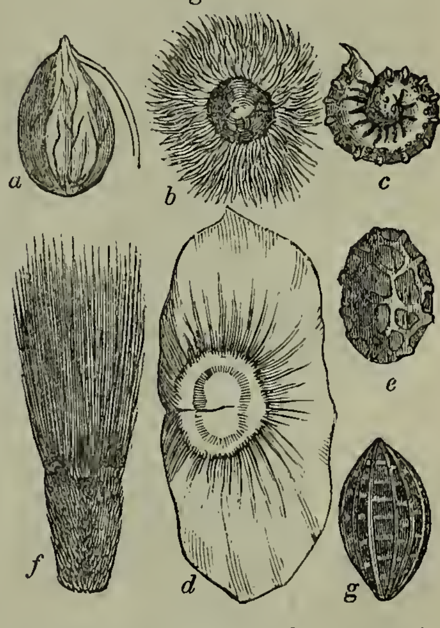
cord of vessels is called the *raphe*, and their expansion, which corresponds with the base of the kernel, the *chalaza*. It will, therefore, be obvious, that where a raphe and chalaza are present, the kernel is inverted, and where they are absent, it is erect: a fact of considerable practical value. This may, indeed, be made out by two other means, either by discovering the foramen, which, in the ripe seed, is sometimes called the *micropyle*, or by dissection; but both these modes are more difficult of application than ascertaining the presence or absence of a raphe and chalaza. Now it has been previously stated (p. 46), that the radicle of the embryo is uniformly found next the foramen; and from this and the other facts just recited, two axioms of the greatest practical value in examining seeds are derived. 1. *When there is neither raphe nor chalaza, the kernel of the seed is erect, and the embryo inverted.* 2. *When a raphe and chalaza are present, the kernel is inverted, and the embryo erect.*

When fully formed, the seed separates from the placenta, retaining a scar, called the *hilum* or *eye*, at the spot where the separation takes place. In some seeds this hilum is very minute, in others it extends more than half round the seed in the form of a broad belt, as in the genus Dolichos.

The integuments of the seed, called collectively the *testa*, or skin, are uncertain in number, like those of the ovule, of which they are merely the ripe state. While, however, they may be fewer in consequence of one or more of them disappearing in the course of the transition from ovule to seed, they never can be more numerous. Two integuments are very obvious in the walnut, the outer of which is brown and tough, the inner white and filmy; and a similar structure is apparent in the almond; in the gourd there is a thin exterior skin, a hard intermediate crust, and a fine inner membrane lying immediately upon the embryo; in the two first cases, the primine and secundine only are discernible in the ripe seed; in the third, the tercine also may be separated.

Nothing can well be more beautiful than the marking of the surface of seeds, especially the minuter kinds, nor anything more varied. In the common Almond, the whole surface is regularly veined by ramifications of the raphe (*fig.* 71, *a*): in the Primrose, it is marked with little projecting points; in a Brazilian plant named Physostemon, it is coiled up like a snail (*fig.* 71, *c*); in Snapdragon, it is marked all over with deep impressions (*fig.* 71, *e*); and in the Prickly poppy it is ribbed and barred across like a closely-grated prison window (*fig.* 71, *g*). Of the

Fig. 71.

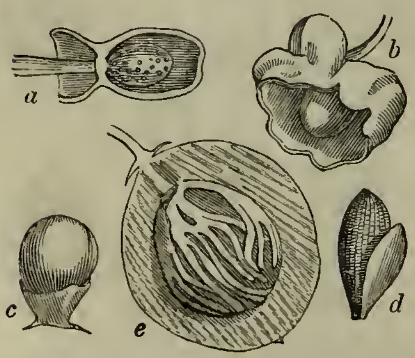


greater number of seeds the surface is perfectly bald, but there are some remarkable for their excessive hairiness: the Cotton-seed, for example, is enveloped in long hairs which grow from every point of its surface, and form the substance so extensively used in manufactures (*fig.* 71, *b*); in the Oleander and similar plants (*fig.* 71, *f*,) the hairs are chiefly confined to one

end of the seed, and appear destined to carry it aloft in the air so as to be conveyed to a distance from its spot of birth. Nor are hairs the only means of transport through the air which seeds possess; some have broad, membranous expansions, called *wings*, the office of which they really seem to serve, as in Bignonia, and plants allied to it (*fig.* 71, *d*).

It frequently happens that seeds are attached to the placenta by a sort of stalk, called the *umbilical cord;* which is an extension of the placenta itself, and consists of a bundle of nourishing vessels surrounded by spongy matter. In its ordinary state, the umbilical cord rarely attracts much attention; but it sometimes assumes a very remarkable appearance. In the common Spindle-tree (Euonymus), the seed is enveloped in a red fleshy bag, which is open at the mouth, and which is an expansion of the top of the umbilical cord just below the hilum (*fig.* 72, *b*). An organ of this sort is called an *aril;* the most remarkable instance of it occurs in the Nutmeg, in which it forms the mace of the shops, being a tough, lacerated, fleshy body, overlapping the whole of the seed (*fig.* 72, *e*): in an almost equal state of development it occurs in the Akee plant (Blighia sapida), in which it forms a fleshy, eatable fungosity, in which the seed is half buried. In the Passion-flower it is a pulpy hood, quite enclosing the seed (*fig.* 72, *a*);

Fig. 72.

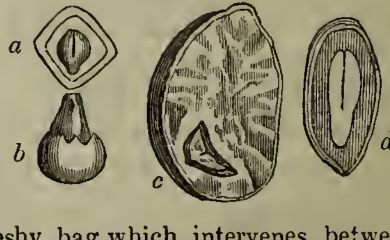


in Heart-seed (Cardiospermum), it is a little plate (*fig.* 72, *c*); and in Turnera it is only a scale standing by the side of the seed (*fig.* 72, *d*). The uses of this organ are unknown; it is however to be remarked that it is never formed until after the fertilization of the ovule has been accomplished.

It has been already stated that the embryo is originally formed in the midst of the pulpy substance of the kernel, and that it is nourished by it during its growth. This pulpy matter bears, apparently, much the same relation to the embryo plant as the white of an egg to an embryo bird; and hence it has obtained the name of *albumen* (*fig.* 73, *c d*). In a very great number of cases this substance is so wholly absorbed by the embryo, that no trace of it is left behind; but in others it remains interposed between the skin of the seed and the embryo, in the form of a horny, or mealy, or fleshy, or oily substance. These differences in its texture are owing to the nature of a substance secreted during the formation of the seed within the cellular tissue of the kernel, and replacing the fluid matter consumed by the embryo; a substance which, in Corn, consists of farinaceous matter adapted for the food of man; in Coffee, of a stimulating secretion, the infusion of which forms a grateful beverage; and in the Poppy, of greasy matter, from which a valuable oil is extracted; but which, in all cases, seems more particularly destined for the nutrition of the embryo in its infant state. If a part only of the cellular substance of the kernel is filled with a solid deposit, and another part remains empty after having been drained by the embryo, the albumen will, in that case, represent a heterogeneous mass, full of irregular cavities, among which solid matter is interspersed, as in the Nutmeg and some other plants. Albumen of this kind is called *ruminated* (*fig.* 73, *c*).

These are generally the only parts of a seed of any importance except the embryo, of which we shall treat in the succeeding chapter. There is, however, in some cases, an additional part called the *vitellus*. In the yellow Water-lily (Nuphar luteum), there is a

Fig. 73.



fleshy bag which intervenes between the albumen and embryo, enclosing the

latter (*fig.* 73, *a*); a similar structure occurs in a few other instances, especially in all species of the Ginger tribe, where it forms a sort of cup, beyond which the embryo protrudes (*fig.* 73, *b*). This part, which is, in reality, the innermost integument of the ovule, in an indurated state, is the *vitellus;* and before the anatomy of the ovule had been made out by Brown and Mirbel, was a very puzzling organ for botanists to account for. Its use is unknown.

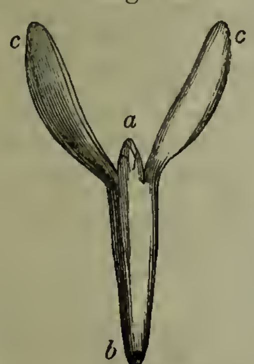
From what has gone before, it is clear that the ovule is the origin of the seed; and as nearly all ovules are originally enclosed within a carpel, there can be no such thing as naked seeds except in a very few instances. What the old botanists called naked seeds were usually achenia; and true naked seeds are hardly known beyond Coniferous and Cycadeous plants; concerning which see the Systematic part of this Treatise.

Chapter XXIII.

Of the Embryo.

This part is so extremely varied in its structure, that it is absolutely necessary to take some one form as typical of the remainder, if the endless modifications it exhibits are to be correctly understood. For this purpose let *a b*, *fig.* 74, represent the central portion or

Fig. 74.



axis of any embryo, and *c c* two *seed-leaves* called cotyledons, growing from it. The part from *a* to *b* will then represent a stem, of which *a*, called the *plumule*, is the growing point; *b*, the *radicle*, is the root; and the intermediate space between the radicle *b* and the base of the cotyledons *c*, an internode: upon which supposition the plumule will be axillary to both cotyledons at once. From this form of embryo all our ideas of that organ may be derived: it represents more particularly what is called a *diçotyledonous* embryo, in which not only there are two cotyledons, but they are opposite to each other; let the number of cotyledons be increased, all other things remaining as before, and it is *polycotyledonous*, as in Fir trees (*fig.* 75, *d*).

In the Lime tree (Tilia) the cotyledons are broad, thin, and leafy (*fig.* 75, *c*); in the genus Ardisia, they are very short, while the radicle is undulated and very long in proportion (*fig.* 75, *b*); in Cactus they are almost rudimentary (*fig.* 75, *e*); in the Horse-chestnut they grow together by their faces into a solid body, enclosing the plumule.

Usually they are undivided, but in the loop-holed Menispermum they are pierced with holes (*fig.* 75, *a*); and in some Cruciferous plants are deeply gashed.

Fig. 75.

Ordinarily they lie flat face to face, but there are many exceptions to this; in the common Maple (Acer campestre) they are folded and plaited something like a bat's wings (*fig.* 75, *g*); in the Pomegranate they are rolled round each other in a spiral manner (*fig.* 75 *f*); in Cordia myxa they are plaited in such a way, that when cut through horizontally, they resemble the quilling round a lady's gown; in the Chocolate plant (Theobroma cacao) they have a broken and most irregular arrangement, forming when within the seed an oblong wrinkled body (*fig.* 75, *h*).

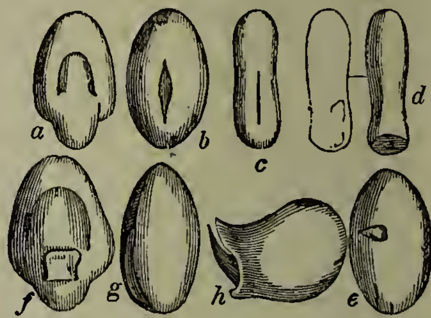
Commonly the embryo is straight or but slightly curved; but in certain

plants it is rolled up in a singular way; in the Chalcedonian Lychnis, and many species of the same natural order, it is *annular*, that is, curved into the form of a ring, the summit of the cotyledons touching the point of the radicle (*fig.* 75, *l*); in the Caterpillar plant (Scorpiurus) it is folded so as to resemble the letter S; and in Dodder (Cuscuta) it is spiral (*fig.* 75, *k*).

All the foregoing modifications are easily intelligible upon reference to the typical form of the embryo; but there are others called *monocotyledonous*, because they have only one cotyledon, in which the analogy between them and the supposed type is at first sight not apparent. Take, for instance, the embryo of a Cocoa-nut (*fig.* 76, *d*); it is a taper fleshy body, somewhat club-shaped at one end, and abruptly blunted at the other; no trace of cotyledon, plumule, or radicle, is externally discoverable. If however it is divided with a thin and sharp knife from top to bottom into two equal parts, it will be found that near the blunt end there is an internal conical tumour directed upwards; this is ascertained by the germination of a cocoa-nut to be the young *plumule;* and this being known, it follows that the abruptly blunted end of this embryo is the radicle, and the other the cotyledon; hence it derives its name of *monocotyledon*.

But although thus much is to be determined without great difficulty, there still remains a want of proof that the so-called single cotyledon is not in fact composed, like that of the Horse-chestnut, of two grown together. The demonstration of this is by a curious series of proofs. 1. The embryo of an Arum is like that of a Palm, only there is a slit on one side of it through which the plumule easily escapes (*fig.* 76, *c*). 2. In Rice (Oryza) this slit is very much lengthened and widened (*b*). 3. In Barley the plumule projects beyond the slit, leaving a flat cotyledon on one side (*a*); and 4. In Wheat the embryo has the structure of Barley, with this most important exception, that at the base of the plumule in front there is a rudimentary cotyledon alternate with the large flat one, on the opposite side of the plumule (*f*). Hence we are to infer that the monocotyledonous embryo of a Palm *is analogous to that of a dicotyledon, of which one of the cotyledons is abstracted, and the other rolled round the plumula and consolidated at its edges.* And this is the view that must be taken of the monocotyledonous embryo in general, all the modifications of which seem reducible to this standard.

Fig. 76.



Thus in Sea-wrack (*fig.* 76, *g*) (Zostera marina) of which the embryo is an oblong almond-shaped body with a cleft on one side, in the cavity of which a long flexuose process is placed, the latter is the plumule, and the former at one end the cotyledon, and the radicle at the other; in Ruppia maritima, whose embryo is an oblong body, cut suddenly off at one end (*fig.* 76, *h*) on which a sort of curved horn crouches, the latter is the plumule, and the former chiefly cotyledon; and so in Frog-bit (Hydrocharis morsus ranæ), the embryo of which is an oblong fleshy kernel with a hole on one side, in which there lies a short cylinder; the latter is the plumule, and the former the cotyledon. It is amusing to compare these simple explanations with the overstrained and far-fetched notions of the late Professor Richard of Paris, as set forth in his *Analyse du Fruit*, translated by Lindley some fifteen years ago. At that time no one had a notion of the true theory of the structure of fruits and seeds, the luminous views of Göthe, although for above twenty years before the public, not being known to a single individual in this country, and all that concerns the seed being still an unexplained mystery.

The embryo called acotyledonous, not being the result of specific fertilization, is not, properly speaking, an embryo at all, and will be adverted to in another place

Chapter XXIV.

Of Abortions, Degenerations, Adhesions, &c.—Of Flowerless Plants.

What has been stated in the preceding pages is to be understood to relate to organs in their usual state; and to be explanatory either of what may be considered normal structure, or, at all events, of deviations which are easily reconcilable with it. This Treatise would, however, be incomplete without some account of the principles upon which it is conceived that all great exceptions to normal structure may be accounted for, and by which they may be reduced to such types as those already spoken of. But as the limits of such a sketch as this forbid the question to be examined in much detail, a few examples only will be given in connexion with very general views.

It must be obvious, from all that has as yet been advanced, that the different parts of which plants consist are extremely simple in their nature; and it is a matter of surprise that such a prodigious diversity, not only of general appearance, but of arrangement and structure, as the vegetable kingdom presents, should result from their combinations. Some French author has indeed said that vegetation is the masquerade dress of nature; it is, however, a masquerade which forms a disguise only to the eyes of those who look at Nature without studying her.

The three principal modes in which the true or typical structure of plants is obscured, are *abortion*, or the non-development of organs; *degeneration*, or their imperfect development; and *adhesion*, or the growth of one to the other.

The term abortion would seem to express, that a part shortly after its original creation became deformed and ceased to have the power of further development; such, however, is not the sense in which botanists use it. By abortion they mean the non-appearance of some organ at the place where one would expect that it would appear, and where in fact it would be found if the structure were regular. There are no parts of plants that may not become abortive, either accidentally or normally; for instance, even in branches, it is their abortion in Pine trees which causes the fascicled appearance of the leaves of such plants; if the greater part of their branches were not abortive, the leaves would not be fascicled, but alternate as in common firs. In leaves, very curious instances of abortion take place; it is by that of the leaflets of Acacias that phyllodia are caused to develope (p. 27); and it is the same cause which produces in Stapelia, Euphorbia, Cactus, &c., those remarkable stems (p. 13) which seem to us as leaves. It is this, also, to which we are to ascribe the peculiar appearance of such plants as Chara, Duckweed, and submersed Algæ.

Thus the abortion of the calyx and corolla produces the kind of flowers we find in the Willow, and to that of either the pistil or the stamens is wholly to be ascribed the existence of what are called unisexual flowers. In all plants it is normal that the number of parts in the corolla, or the stamens, or the pistil, should not be less than the multiple of the numbers in the calyx; and all exceptions to this are ascribed to abortion. Thus Lamium, the white Dead nettle, has a calyx with five teeth, a corolla which is reducible to five petals; but only four stamens; in this case one stamen is abortive, as is proved by plants like Pentstemon, in which that becomes developed which is usually undeveloped. A part of the petals in like manner is, in some instances, abortive; as in Cuphea, which wants a part in some species, and the whole in others; and in Daphne, in which all the petals are always abortive. This term is also applied to parts which, although once completely formed, nevertheless become abortive in the course of their growth, as is the case with part of the ovules and carpels of Cupuliferous plants, as is explained at p. 47, as is common in many Palms, and as usually happens in the Rose itself between the fertilization and maturity of its fruit.

Degenerations are a much more fertile source of alteration in appearance; they generally consist in a part being less highly developed than is usual; and may be considered—if viewed in their true light—as explanatory of the true basis of comparative anatomy in the vegetable kingdom (see p. 59). As instances of this, among leaves, may be quoted such plants as Ruellia anisophylla, in which one of the leaves of each pair is minute and unformed; or as Monotropa hypopithys, the bird's-nest Orchis (Neottia), Scalewort (La-

thræa), and many others, all whose leaves are in the degenerate state of scales; the scaly coverings of leaf-buds are also imperfectly formed or degenerate leaves. The calyx is remarkable for the many shapes it assumes when degenerated; in the Elm and the Beech it is nothing but a thin, green, deformed membrane; in the fertile flower of the Fig it is a few unequal bristles; and in many Composite plants it consists of little more than hairs or sharp-pointed scales; and is often so entirely rudimentary as to be nothing but a narrow rim. In like manner the corolla is reduced to a few scales in Buckthorn (Rhamnus), and its interior petals to thread-like processes in the Passion-flower. The stamens again are in part not more developed than as little scales in Scitamineous plants; in Lopezia appear in the form of a spoon-shaped membrane; in multitudes of plants are little awl-shaped processes resembling filaments; and in a curious New Holland genus called Eupomatia, they altogether assume the appearance of petals (*fig.* 76*). Even ovules in a degenerate state are thought to be discoverable in the form of the glands which grow upon the edge of the leaf of a Peach-tree.

Fig. 76*.

But whatever deviations from normal structure may occur in consequence of abortions and degenerations, they are as nothing compared with what is produced by the adhesion or growth of one thing to another, a phenomenon on which depends the very existence of plants as organic beings. Their whole framework is constituted of minute organs in a state of adhesion; their stems may be understood, without doing violence to truth, as combinations of many systems of life; and we see perpetually the existence of this tendency evinced in accidental cases, such as the growth together of two Cucumbers, or of two Apples, or of two or more stems which have been developed in contact with each other. In the hedges, where branches are intertwined very closely, one branch frequently grows to that which is next it, forming a complete natural but accidental union.

This property, which exists thus extensively, is of great and continual operation in veiling the real nature of all the external parts of which plants consist, whether of vegetation or of fructification. Leaves, for instance, grow together by their bases (p. 28, *fig.* 32); the adhesions of stipules cause the production of ochreæ, and that of bracts is the explanation of the cupule or cup of an acorn (p. 33). So are most of the modifications of fructification produced by the agency of the same tendency. The calyx, for example, is normally composed of a certain number of sepals; they grow more or less together, and constitute a toothed cup, a tube, or even an undivided cylinder; the petals also adhere into parts of a similar nature, forming monopetalous corollas; the filaments combine into a sheath for the ovary (*fig.* 51, *f*); the anthers grow into a sheath for the style in Composite plants; the carpels, styles, and stigmas combine to form syncarpous pistils (*fig.* 55); calyx, corolla, filaments, and ovaries, all coalesce into one solid body to form an inferior ovary; and finally, in Orchis, the filaments, anthers, style, and stigma, are consolidated into one columnar mass.

These instances, and a volume might be filled with others such, are abundantly sufficient to show the prevalence of the law, *that all contiguous parts are liable to grow together.*

It must however be remarked, that in all cases of normal adhesion, the growing together seems to take place at a very early period of the formation of the organs; and to be altogether antecedent to their arriving at a perfect state.

Flowerless Plants.—It is probable, although it is not yet susceptible of proof in many cases, that all the curious deviations from typical structure which occur among flowerless plants, are owing to the operation of one or other of the foregoing causes. For example, there can be scarcely a doubt that the repro-

ductive organs of Equisetum are degenerate stamens and pistils; that those which grow on the back of the leaves of Ferns are degenerate leaf-buds; and that the thecæ of Mosses are of a similar nature, although in an extremely different state. So in like manner the scales of Mosses must be considered degenerate leaves; the shining green horizontal expansions of Marchantia adhesions of degenerate leaves to degenerate stems; while the reproductive organs of both Lichens, Fungi, and Algæ are to be reckoned adhesions, abortions, and degenerations of well-known organs, all in one. We do not however propose in this treatise to meddle with this part of the subject, otherwise than in the most incidental manner possible.

Chapter XXV.

Of the Theoretical Structure of Flowers, or Morphology.

Notwithstanding all that has been said concerning the normal or abnormal state of the organs of plants, and the manner in which they are severally combined, there still is wanting some principle of combination by which the relation that they severally bear to each other can be determined, and consequently the existence of abortions or degenerations, which are in all cases interferences with regularity, be detected.

It does not appear that the old botanists, who in fact knew nothing whatever of the theory of structure in regard to the vegetable kingdom, ever suspected that the different organs of plants bore any fixed relation to each other; nor can it be said that Linnæus at all understood this, however near he approached to a discovery of the key of the theory. See *Lindley's Introduction to Botany*, p. 505. It was only after the poet Göthe promulgated the doctrine, that all external organs, of whatever nature, are metamorphosed leaves, that botanists gained a clue by which the mutual relations of plants could be determined, and a flower be proved to be analogous in its structure to a branch covered with leaves. For this grand discovery of necessity led to the conclusion, that if a flower be really a collection of metamorphosed leaves, and consequently a branch, the parts of a flower must of necessity bear the same relation to one another as the leaves of a branch. And this is the true basis of all ideas regarding the parts of fructification of plants. It may indeed appear ridiculous to assert that the fruit of a peach is nothing but a peach-leaf rolled up and thickened, an apple only the leaves in a similar state, and a grain of wheat a single leaf in a state of degeneration; and yet we expect to be able to set this matter before our readers in so clear a light, as to convince them that such an assertion, although startling, would be very nearly true. This is called the doctrine of morphology.

It has been observed, in a report made to the British Association at their meeting at Cambridge in 1833, when adverting to this doctrine, that when those who first seized upon the important but neglected facts out of which the modern theory of morphology has been constructed, asserted that all the appendages of the axis of a plant are metamorphosed leaves, more was certainly stated than the evidence would justify; for we cannot say that an organ is a metamorphosed leaf which, in point of fact, has never been a leaf. What was meant, and that which is supported by the most conclusive evidence, is, that every appendage of the axis, whether leaf, bract, sepal, petal, stamen, or carpel, is originally constructed of the same elements, arranged upon a common plan, and varying in their manner of development, not on account of any original difference in structure, but on account of special and local predisposing causes; of this the leaf is taken as the type because it is the organ which is most usually the result of the development of those elements; is that to which the other organs generally revert when, from any accidental disturbing cause, they do not assume the appearance to which they were originally predisposed; and moreover, is that in which we have the most complete state of organization. It might have been added that the leaf moreover can always be most distinctly traced by insensible gradations of structure into all the other parts. It is this which we now propose to prove; and being proved, it will show the truth o the axiom, that *all the parts of a flower must necessarily be equal to each other in number, and alternate with each other*,, except in cases of abortion, degeneration and adhesion.

The course we shall take is this; we shall prove, 1. The bract to be a modification of a leaf; 2. The sepal to be a modification of a bract; 3. The petal of a sepal; 4. The stamen of a petal; 5. The carpel of a leaf; and 6. The ovule of a leaf-bud; and we shall then have demonstrated the whole of them to be modifications of leaves. It is also to be remarked that if this can be proved of *any* normal plants, it must be true of *all* such; for as their parts are manifestly identical in nature, that which is true of one is necessarily true of all.

It must require but little evidence to convince the most sceptical reader that a *bract* is nothing more than an imperfectly-formed leaf. Examine it in the Lilac; the most gradual transitions may be seen from the one to the other; or examine it in the Pæony, the ivy-leaved Speedwell, and the common briar Rose (Rosa canina). This being established, it follows that all modifications of bracts are also imperfect leaves, and that, therefore, the involucre of an Umbelliferous, or of a Composite, plant, and the cup of an acorn are also aggregations of half-grown leaves. This is step the first.

The transition from a bract to a *sepal* is very easy. In the Strawberry, the calyx is composed of five bracts alternating with the five sepals, and distinguishable from them in nothing but size; in the Pæony, the leaves insensibly pass into bracts, and the bracts into petals; and in the Carolina Allspice (Calycanthus), the same gradual transition is strikingly apparent. Add to this, that in the briar Rose, one of the sepals is always pinnated like the true leaves; that in the Tulip the sepals often become half leaf and half petal; and that in the Apple, Pear, and numerous other plants, a transformation of sepals into leaves is of common occurrence, and the point that sepals also are leaves may be considered established.

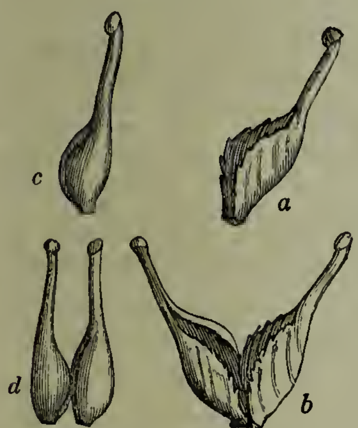
Difference organically between *petal* and sepal there is none, as has already been shown (p. 36); consequently what is true of the one is also true of the other, and petals also are leaves. We may as well, however, add to what has been stated in the place referred to, that petals will occasionally become leaves, or be half changed to them; the latter is common in the Apple and the Pear, it also occurs in some varieties of Rose, and has been seen by Du Petit Thouars in the Tropæolum, by the writer of this in Sieversia montana, and numerous other plants, and may be discovered by any one who will search diligently for it. The petal is, therefore, a modification of a leaf.

A stamen is less obviously like a leaf than any of the preceding parts. And yet if we examine it in the white Water-lily, its relation to a petal, and consequently to a leaf, is incontestable. In the white Water-lily, the innermost petals gradually narrow, and become callous at the point; their edges, also, like the point, become insensibly yellow and dilated; at last a cell full of pollen is formed upon their edges, and a stamen is the result; here it is impossible to distinguish any precise limit between the petal and the stamen, but one is clearly a modification of the other; the same may be said of the Carolina allspice. In double Roses, Pæonies, Tulips, Anemones, Ranunculuses, &c., all manner of transitions from stamens to petals may be detected; and in the Rose œillet of the gardens in particular, it is clear that the filament of a stamen answers to the claw, and the anther to the limb of a petal, consequently the filament is a modification of the petiole, and the anther of the blade of a leaf. The probability of this is further shown by the fact that the two lobes of an anther answer to the two sides of a leaf, and the connective to the midrib; and the fact is proved by accidental productions, such as occur now and then in Umbelliferous plants, where the stamens are replaced by small leaves on long stalks. In special cases of deformation, the stamens become genuine leaves, as in the Sieversia above referred to. The stamen, then, is a modification of a leaf.

That the *carpel* is of the same nature is very easily shown, not only by its constant tendency to revert to the form of a leaf, as is seen in double Roses, Anemones, Ranunculuses, and the like, but more particularly by the double Cherry, in whose flowers Nature has written her laws in a language so simple, and positive, that none but the wilfully blind can misunderstand them. In this plant the centre of the flower is occupied by a small green leaf (*fig.* 77, *a*) stationed in the place of the carpel, and consisting of two sides folded together, along with a midrib which is longer than the leaf itself, and

slightly dilated at the summit. Upon comparing several of these leaves in different states, with the perfect carpel of a cherry (*fig.* 77, *c*), it is obvious that the two inflected sides of the leaf answer to the ovary, the midrib to the style, and the dilated summit of the midrib to the stigma; and if we compare the internal structure of the ovary with a section of the carpellary leaf of the cherry, it will also be obvious that the inside of the ovary answers to the upper surface of the leaf, the ventral suture to the line formed by the union of its two edges, and that the placenta is merely an expansion of a portion of the margin. In some instances two carpellary leaves occur in a flower of the double cherry, as at *fig.* 77, *b*; and then it is found that

Fig. 77.



they are placed directly opposite each other, the margins being nearly in contact; so also when by any accident the cherry has two real carpels, they also occupy the same position with respect to each other, the ventral sutures, and consequently the placentæ, being contiguous (*fig.* 77, *d*). That the carpel of a Cherry is a leaf, admits then of no further doubt, and consequently a Cherry fruit must also be a leaf, because the fruit is nothing whatever but the mature state of the carpel. Nor, indeed, are the changes that take place in the structure of the Cherry between its young and its full-grown state by any means incompatible with the anatomical structure of a common leaf. The stone of a cherry is the hardened lining of the fruit; it is also the upper stratum of the leaf, which consists, as has been already shown (p. 29), of little bladders placed in a different direction from those of the central and lower strata. The pulpy portion of the cherry will then arise from these latter, distended with fluid and altered in colour; the former phenomenon occurs habitually in the leaves of the House-leek, and of all leafy succulent plants, and the alteration in colour is analogous to what happens to the leaves of the purple Beech, the scarlet Maple, black-fruited Vines, Virginian creepers, and many other well-known plants, in the autumn, when they have reached their full maturity as leaves. That the carpel is a leaf is thus proved to demonstration; and as all compound fruits are collections of carpels, as has already been stated (p. 43), it follows that all fruits, of whatever kind, are modified leaves.

The last step in morphology is to show that ovules, and consequently seeds, are also alterations of leaves. As it appears from what has just been said that ovules grow upon the margins of a carpellary leaf, there will at first sight be a difficulty in reconciling such a function with the well-known fact that leaves do not in general bear anything analogous to ovules. But although it is not a general property of leaves to do this, yet it occurs in a sufficient number of cases to justify the conclusion that it may constantly occur in leaves whose ordinary functions are interfered with by their conversion into carpels. In a common Indian plant called Bryophyllum, the leaves are capable of forming young plants in the crenelling of their border; in the rare little Malaxis paludosa of our marshes, Henslow has shown that bulbs (*i. e.* buds, see p. 13), are constantly formed at the border of the leaves; Ferns often root at the segments of their leaves, in consequence of buds being formed there; so that the production of buds by leaves is not unknown. Now it is to buds, or bulbs, that ovules are to be compared; their integuments are to be considered rudimentary leaves, analogous to the scales of a leaf-bud, and they have actually been seen by Henslow, Engelmann, and others, to change into minute leaves in certain cases of malformation. It is no wonder, then, that bulbs, buds, and seeds (or ripened ovules), should all have a similar power of propagating plants, considering that they are all mere modifications of one common type.

It still remains to be proved that the scales of a leaf-bud, to which we have said that the integuments of an ovule are analogous, are themselves modified leaves. It is true that, if we compare the hard shining resinous scales of the Tacamahac poplar, or the brown woolly scales of the scarlet Horse-chestnut, with the leaves of those trees, we shall be at a loss to discover any resemblance between them; yet by watching them in their growth in the spring, when the leaves are first unfolding, we shall make out their identity in the clearest manner. Take, for instance, the scarlet Horse-chestnut, or the Sycamore. As soon as the buds are unloosened by the movement of the vital principle within them, the outer scales, which are dry and dead, are gradually forced asunder by others, which, although like them in form, still maintain their living powers; of these latter the most exterior lengthen a little, becoming green at their base, but remaining scale-like at their point; those next within them become greener, and have no hardness at the end, otherwise resembling them; the next that are formed produce a little leaf at their points, and themselves contract into a narrower compass, resembling a petiole; finally a greater degree of contraction at the base and of expansion at the point is produced, and a perfect leaf is the result. By this means we are able thus to trace in the clearest manner the identity in nature between the scales of leaf-buds and leaves themselves, and consequently to show that the former are a stunted form of the latter.

Thus by a process of reasoning, and of demonstration, in which no fallacy can be involved, and in which not a single flaw is to be pointed out, we are able to show that all the parts of a flower are modified leaves, analogous to modifications of another nature, which exist in the form of scales of a leaf-bud. Consequently a *flower is a collection of leaves placed in whorls, and therefore is a branch with a short axis.* This explains how it happens that one flower will grow out of another; how monstrous Pears are formed, in which tier upon tier of fruit rise, from a common stalk; for as the parts of a flower are leaves, they must have, like leaves, the power of forming buds in their axils; generally they do not form them, but if they do, the result may either be a common branch growing out of a flower, as in many Roses, or a new flower changing to fruit, as in malformations of the pear.

These principles being established, they are necessarily followed by certain results, which form the basis of the present theory of floral structure; and which may be considered to have conduced more to improve our knowledge of botany than any other circumstance that has occurred in its whole history. These results are:—

1. *That each series of floral envelopes must normally alternate with that which preceded it.*

2. *That the number of parts in every series must be equal to, or a multiple of, the number of parts in the first or outer series.* And

3. *That all exceptions are owing either to multiplication, abortion, or adhesion of parts.*

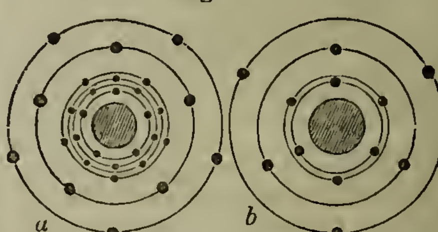
A few words only are necessary to demonstrate this.

That every series in a flower must necessarily alternate with that which precedes it, that is to say, that petals must alternate with sepals, stamens with petals, and carpels with stamens, as is well shown in the houseleek, is founded upon the necessary alternations of leaves when placed in whorls, as is explained at p. 22, to which the reader is referred.

That the number of parts in each series must be the multiple or equal of the number in the outer series, is a necessary consequence of the last rule.

That it may, however, be interfered with by such causes as multiplication, abortion, or adhesion, may be easily conceived, and will be as easily understood by a few examples. First, as to *multiplication*. a Cherry (*fig.* 78, *a*) has a calyx composed of *five* sepals, a corolla of *five* petals, and *twenty* stamens; here four rows of stamens are considered to be present, all, however, blended into one whorl by the closeness of their origin. A Squill (*fig.* 78,

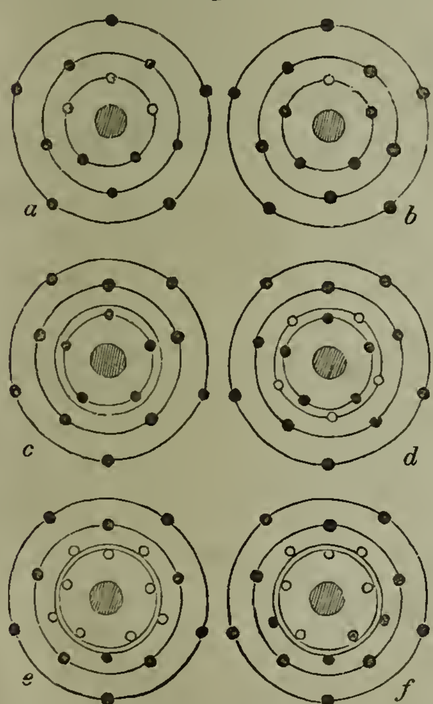
Fig. 78.



b) has *three* sepals, *three* petals, and *six* stamens; that is, two rows of the latter, the first of which alternates with the petals, and the second with the first. This will be at once obvious if, in the above and succeeding diagrams, the outer circle is considered as calyx, the next as corolla, the following as stamens, and the centre of all as pistil; the black dots as indicating the position of organs, which are present in a perfect state, and the white dots those which are abortive.

Secondly, as to *abortion:* a Sage flower (Salvia) has a calyx of *five* sepals, a corolla, which, however irregular, is made up of *five* petals, and only *two* stamens (*fig.* 79, *a*); here three stamens are abortive; and upon looking attentively at the inside of the tube of the corolla, two little scales are often to be seen growing alternately with the petals, exactly in the place where the stamens themselves should normally have appeared: two of such scales are very often in other genera, other-

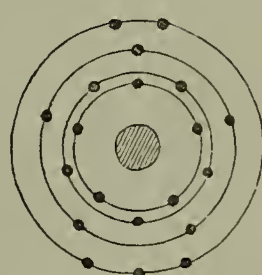
Fig. 79.



wise constructed exactly like the Sage, developed as perfect stamens (*fig.* 79 *b*); and in some others even the fifth makes its appearance, exactly where it should normally be found. In the Primrose the stamens are equal in number to the petals, but opposite them (*fig.* 79, *c*); in this case the first row of stamens is abortive, and the second, which is the only one that developes, is in its true position; while in Samolus, a plant otherwise formed upon the same plan as the Primrose, five scales, which are degenerate stamens, appear in the situation of the first row (*fig.* 79, *d*). In the genus Bauhinia there are species in which, out of ten stamens five only are perfect, or even a smaller number (*fig.* 79, *e f*); the other parts remaining in a normal condition. In the carpels, deviation from the true number, in consequence of abortion or non-development, is so common as not to be worth reciting.

It is, however, after all, in adhesions more particularly that apparent deviations from normal structure take place. A papilionaceous flower consists of five petals (p. 38); the calyx should, therefore, consist of five sepals; but in the Lupine, and many others, only two sepals are discoverable. In reality there are five, although they are so combined that their true number is invisible; two uniting into an upper and three into a lower lip of the calyx (*fig.* 80); and in like manner petals

Fig. 80.



adhere till their true number is lost sight of, as in the white Dead-nettle, the calyx of many Labiate plants, and a host of other things.

The reader may, however, be assured, that in all such cases the normal proportions are easily discoverable, and that the laws deduced from such morphological considerations as those which have been explained, are fixed and immutable.

In strictness it is in this division of our subject that we ought to treat of the structure of what are called the elementary organs of plants, to which we have already alluded under the name of bladders, air-vessels, &c. But as they may be considered the springs by whose united forces the functions of vegetation are exclusively regulated, and as it is through their agency that the powers of earth, air, and light are brought to bear upon the living system of a plant, and to produce all those curious phænomena of which we shall have to speak almost immediately under Physiology, we believe the plan of this treatise will be best preserved by deferring an explanation of the elementary organs till the appearance of the next part of our undertaking.

Part II.—Physiology.

Chapter I.

Of the Elementary Organs; Cellular Tissue; Woody Tissue; Vascular Tissue.

Although plants are furnished, as has now been seen, with many different organs, by means of which the various actions of their life are performed, yet it would be physically impossible for those organs to adapt themselves to the numerous atmospherical and other conditions to which they are exposed, and to feed, breathe, digest, or grow, deprived as they are of everything like the voluntary powers of animals, if it were not for certain small but highly organized parts, of which they, and all the organs of which they consist, are composed. These parts, the minuteness of which is such as to escape the observation except when aided by powerful microscopes, by adhering to one another in particular directions, now spreading into thin plates, now accumulating in solids of various forms, constitute the stem, and root, the leaves and all that to them appertain, and, consequently, the flowers, fruit, and seed of plants, which thus are to be considered masses of a highly curious mechanism, endued with the vital principle.

Such minute parts, being the organic elements of plants, receive the name of *elementary organs.* They may be described as being closed sacs, formed of an exceedingly thin transparent membrane, and assuming different forms, according to the duties they may have to perform, now thickening at their sides, now lengthening, now forming a spiral thread in their interior, from which they gain elasticity, extensibility, and a certain degree of impermeability.

The mode of illustration adopted in this treatise being by no means favourable to the representation of the appearance of such organs as these, they will be treated of very concisely; especially as the most general notion of their nature is sufficient to enable the botanist to understand their mode of action, provided his notion is accurate as far as it goes; all beyond general statements belongs to Vegetable Anatomy, of which we have no intention to treat in detail.

§ 1.—*Cellular Tissue.*

The most important and the most common of the elementary organs is cellular, or, as the French better call it, vesicular tissue. When cut through, as in the pith of the Elder, it appears something like fine honeycomb, the sides of whose cavities, although resembling a hexagon, are nevertheless exceedingly irregular. If a portion of it is put into water and looked at by transmitted light, it will be found nearly colourless and transparent; and if it be boiled for a short time in water, having a small quantity of potash dissolved in it, it may be easily rubbed between the fingers into exceedingly minute bladders. It was these bladders, or *vesicles*, the sides of which, when cut through, caused the honeycomb-like appearance that was first seen. In their natural state, they adhere firmly to each other; but boiling in a solution of potash destroys their adhesion and sets them free. The pulp of a Strawberry, in like manner, consists of cellular tissue; but instead of being empty, as in the Elder, each little bladder is filled with coloured fluid: in this instance the cells or bladders adhere so loosely that they may be separated by merely rubbing the pulp gently in water. In half-dry fruits, like the Jujube, the mealy matter in the inside of the dried pods of the Tamarind, or the Carob bean, the cells separate spontaneously. Cellular tissue is composed, then, of cellules or little bladders in a state of adhesion; and every partition in a mass of cellular tissue must be double, because it consists of the two united sides of two cellules in contact.

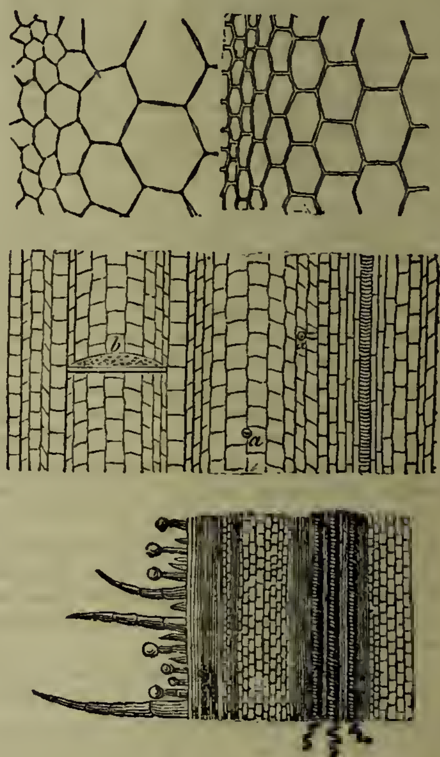
Cellular tissue is most commonly composed of an exceedingly fine transparent membrane; but this latter, in some cases, as on the outside of leaves, or in the bony parts of fruits, becomes so extremely thick, that its very cavity is closed up. In either case, it appears to the eye, even when aided by the most powerful magnifying glasses, to be perfectly homogeneous, without a trace of lines, or holes, or nettings, or of anything of the sort; but, as it has been shown by Lindley to tear with a ragged edge (*Introduction to Botany*, p. 2, t. 1, f. 6), there can be little doubt that its ultimate molecules are arranged in such an order, that they adhere more forcibly in one direction

than in another; and this is rendered the more probable by the tendency which this kind of tissue has to slit and tear in a definite manner when stretched, after being full-grown. An infinite variety of forms, in which this takes place, has been remarked by Purkinje, in the lining of anthers, and elsewhere.—(*See the same work*, p. 10, plate 2).

In size the cellules of cellular tissue vary from the $\frac{1}{1000}$ to $\frac{1}{30}$ of an inch. In some Fungi they are so small, that it has been calculated that a sphere of the size of a large Gourd will contain forty-seven million millions; a number so large that it is difficult for the mind to comprehend it without something to compare it with; it will be more intelligible if it is remembered that if all the cellules of such a gourd are arranged side by side, and two hundred of them covered an inch, which is about their computed size, they would extend rather more than nine hundred miles.

The primitive form of a bladder of cellular tissue is supposed to be the dodecahedron, and it is thought that all other forms are produced by extension or compression. If, for instance, the two poles of such a solid were to be extended, a spindle-shaped bladder, or a prism, or even a cylinder, might be the result; if, on the contrary, its sides were pressed together, it might become a thin disc; and if both extension and compression act simultaneously, other forms might be the result. Thus we find when the cells of plants are formed in a nearly unresisting, or in an equally resisting medium, they assume most nearly the form of some regular spheroid, as in the pith and the pulp of leaves and fruits. When they are generated in parts growing with great rapidity in some particular direction, as in the succulent stems of many herbaceous plants, the stalks of leaves, &c., they assume a prismatical or cylindrical form; and when they are jammed firmly between harder bodies, as in the medullary processes, they become thin plates. This is particularly conspicuous in the medullary processes, the cellular tissue of which is called *muriform*, because, consisting of regular thin parallelograms, it looks as if built up with bricks, as the wall of a house is (*fig.* 89). In some cases, as in the inside of leaves, the cellules look as if lobed, as is represented at page 29, *fig.* 34; this may in some measure arise from the unequal pressure of air upon them at the time of their development; but it is chiefly an optical deception, the lobes being nothing more than cells grown irregularly together.

Fig. 81.

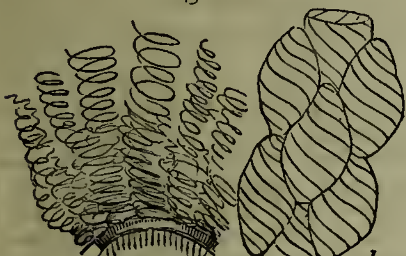


The kinds of cellular tissue which have now been described, however different from one another, are nevertheless very obviously slight modifications of one primitive type; besides these, there are others which are less easily reducible to it. These are *fibro-membranous* and *fibrous*, and what are called *dotted ducts*.

Fibro-membranous (or *reticulated*) *cellular tissue* (*fig.* 82, *b*) is common cellular tissue, with a spiral fibre generated in the inside of each cell or bladder. It has no elasticity, nor anything, as far as we know, to distinguish it, except this circumstance; its most usual situation is in the skin of seeds, in some of the winged kinds of which it is a most beautiful object, as in those of Eccremocarpus scaber; it constitutes the entire plant of the moss Sphag-

num; forms the tubes called *elaters*, by means of which the spores of Jungermannias are dispersed; and is met with occasionally in the inside of the leaves of many plants. The particular use of this tissue is unknown.

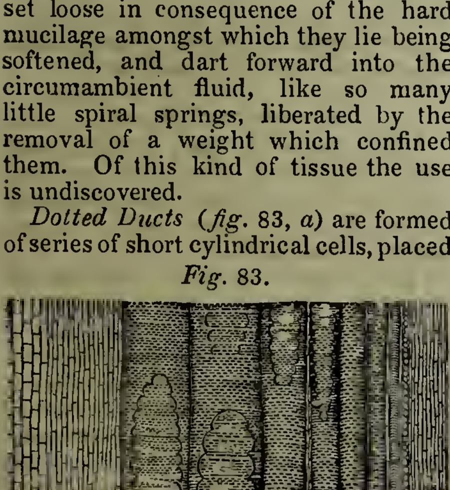
Fig. 82.



Fibrous cellular tissue is more uncommon; it is formed by a fibre either twisted spirally, or arranged irregularly, *without any membrane;* by which circumstance it is immediately known from all other elementary organs. In the lining of the anther it is very common; and it also exists upon the surface of certain seeds, which, when moistened, become covered with mucilage, such as Wild Clary (Salvia Verbenaca) and Collomia linearis (*fig.* 82, *a*). If a seed of this latter be placed under a microscope in water, it will, in a few moments, project from its surface an immense multitude of little spiral threads, which expand in the water and surround the seed like a coating of the most delicate gauze. This appearance is produced by the liberation of the cells of fibrous tissue, which are set loose in consequence of the hard mucilage amongst which they lie being softened, and dart forward into the circumambient fluid, like so many little spiral springs, liberated by the removal of a weight which confined them. Of this kind of tissue the use is undiscovered.

Dotted Ducts (*fig.* 83, *a*) are formed of series of short cylindrical cells, placed

Fig. 83.



end to end, so as to constitute slender columns, extending the whole length of many stems. These cylinders are more or less oblique at their extremities, and are always marked with rows of dots, which appear to be grains of green amylaceous matter; at first, the ends of the cylinders are imperforate, and, consequently, each column is composed of a vast number of closed cavities; but, after a time, the ends of the cylinders are torn open, and the cavities communicate freely with each other, so as to form a tube. At the places where the short cylinders join, oblique lines are seen externally, which are caused by the junction of the cylinders, and being usually more or less oblique, they give the dotted duct something the appearance of a modification of the spiral vessel: hence it has usually been referred to vascular tissue. It is, however, quite certain, from the inquiries of modern observers, that it is, in fact, such a modification of cellular tissue as we have described. Much uncertainty exists as to its real office; it appears, when first formed, to contain air; but after the rupture of the ends of the cylinders it certainly is filled with fluid at the time when the sap is most rapidly in motion; and afterwards it again becomes empty. It is exclusively found in the wood, of which it is one of the parts most early formed. When you look at a transverse section of a piece of Oak or Hazel, or Cane, the little holes which give those woods a porous appearance are the mouths of dotted ducts. They are unknown in Coniferous trees, are unfrequent in herbaceous stems, but may be found with great facility in thin slices of the wood of beach or oak.

Cellular tissue of the common kind, bears the same relation to the vegetable as flesh to the animal frame. It is the basis of every part of which a plant consists; and very often, as in Mosses and the lower tribes of vegetation, it is the only kind of tissue that is formed. In trees, and other woody plants, it constitutes exclusively the pith, the parenchyma of the leaves, the sepals, petals, stamens and carpels, the cuticle, the stigma, and the ovules; in Exogens it forms the medullary processes, and the principal part of the bark; in Endogens it constitutes the whole of the spongy substance in the interior of their stems. It is absent only from the plates of pure woody matter of the stem, and from the veins of leaves, &c., which, in reality, are

an emanation of the woody system. (*See* page 21.)

Cellular tissue is supposed to be capable of performing, by itself, all the more important of the vital actions of vegetation; because there are many plants which live, grow, and propagate themselves, without possessing any other kind of tissue. When combined with other forms it has, however, certain objects in particular, for which it is destined. One of its greatest functions is *to absorb* moisture or gaseous matter, and to part with it again, acting as a sort of living filter. If you place a slice of Elder-pith upon a glass, and allow it to communicate by ever so small a space with water, the whole mass will be speedily saturated; and, on the other hand, it will as speedily part with its water if exposed to a dry atmosphere; not always, however; for in some cases, such as succulent plants, it parts with water very slowly; it, however, does lose it by evaporation through its membranous sides. The latter, then, are eminently hygrometrical, and as they permit mere water to pass through them readily, we must suppose them to be pierced with holes, although the latter are so fine, that the most powerful microscopes that have yet been invented have failed to detect them *.

Having the power of absorption in this high degree, cellular tissue will consequently be well adapted for *transmitting* the fluids of plants from place to place; and accordingly we find it evidently performing this office wherever a very rapid transmission is not required. Being in many cases composed of sacs of a spheroidal shape, it can allow fluids to pass indifferently, in whatever direction a higher-propelling force may exert itself; or when the sacs have an elongated figure, it will then serve to conduct the juices in the direction of the greatest diameter of the sacs. Thus, in pith, there is no particular direction in which the sap is conducted, but it is conveyed by the spheroidal sacs of that part to whatever portion of the contiguous tissue it is required to feed; in the medullary processes, on the contrary, in which the cells are flat parallelograms, with their principal axes directed from the bark to the pith, it is in that direction only that the mural cellular tissue is destined to convey the secretions.

Further, the sacs of cellular tissue being the sole recipients of the sap of plants, properly so called, are the parts in which all the elaboration of the fluid matter of vegetation takes place; it is in them that the crude sap is deposited, in order to receive the influence of light and air; it is in them that it thickens by evaporation, and that it assimilates the various fluid substances that are mixed in it; it is exclusively in the sacs of cellular tissue that the perpetual decomposition of carbonic acid is going on, by means of which the carbon of the atmosphere is refixed and restored to the material substances of the earth; and, finally, it is by the same power of transmission, of which we have already spoken, that the juices, altered and elaborated till they have acquired the properties peculiar to each species, are conveyed from the vegetable stomachs, as leaves may be called, to the bark, stem, and root.

Cellular tissue is moreover the grand agent, by means of which many of what may be termed the mechanical forces of plants are exerted. If, for instance, there are two parts to be torn asunder by contraction, as in the valves of the anther, it is by the shrinking of cellular tissue that it is effected; or if one part is to be burst by the swelling of another, as the Spirting Cucumber, it is to the same kind of tissue that this office is entrusted by nature. In fine, it is the most delicate, the most coarse, the most universal, the most pliable, and the most energetic of all the elementary organs of vegetation.

§ 2.—*Woody Tissue.*

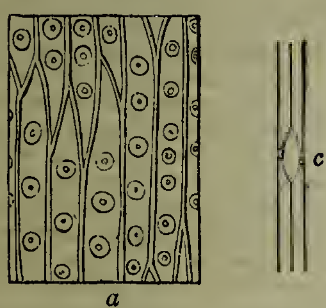
This, which is also called *woody fibre*, consists of thick-sided transparent tubes, terminated at each end in a conical manner, and applied to one another in considerable numbers, so as to form bundles of great strength and elasticity. It is by some considered a mere form of cellular tissue; but it differs most essentially from that in three important circumstances—firstly, in its toughness; secondly, in its very great length; and thirdly, in its tapering extremities. Cellular tissue, when much elongated, usually forms truncated cylinders, as in Cotton, which is a good illustration of it in a lengthened state; when thick-sided it is rarely

* The old opinions concerning the presence of visible pores in the sides of cellular tissue were errors.

tough and elastic; and the longest specimens of tubular cellular tissue are shorter than the shortest specimens of woody fibre. The latter is little subject to variation, except in calibre, in which respect it is found between $\frac{1}{300}$ and $\frac{1}{150}$ of an inch: how slender its tubes usually are may be understood from this, that in hemp, which is a preparation of the woody tissue of the Hemp-plant, it is six times finer than a human hair; each of the filaments into which this substance is mechanically divided before being twisted into thread, consisting of a considerable number of tubes of woody tissue.

It is in Coniferous plants chiefly that the most important of its modifications occurs. In these plants, the sides of the tubes, which are of considerable diameter for this kind of tissue, are marked with large oval glands, which are placed either in single or in double rows, and which appear as if they had a hole or a pimple in their centre (*fig.* 84, *a*). Dr. Mohl, of Munich, has lately

Fig. 84.



endeavoured to show that these glands are shallow depressions or openings from one tube to another, as is represented at *fig.* 84, *c*—the central pimple being in reality a pore; and he represents the appearance of sections of such parts in considerable detail; but as no one has in this country been yet able to detect what this botanist represents, even when assisted by the finest instruments, we must be permitted to doubt whether he has not been misled by imperfect observations; especially as there is no such thing, in fact, as visible pores in any kind of tissue, as far as has yet been detected. What makes *glandular woody-fibre* more remarkable than it otherwise would be, is its exclusive occurrence in Coniferous plants, and genera related to them; on which account it has been found of considerable importance in determining the real nature of many mineralized trunks found imbedded in the early strata of the earth. The reader, who would like to obtain a clear view of it, has nothing more to do than to take a thin shaving of a piece of Pine-wood, such as a carpenter's plane will produce, and to place it in water, beneath a microscope that will magnify about fifty diameters. The great use of woody-fibre is to give strength to every part, and to protect certain of the more delicate organs: it may be considered at once the bones and sinews of vegetation. If it were not for it, the stem of a Willow would be as brittle as that of a Mushroom; but lying as it does across the cellular tissue, it binds it together, and renders all the parts tough by means of its own elasticity and strength. It occurs in the wood, of whose plates or bundles it constitutes the principal part; in the bark, in smaller quantity; in the stalks and veins of leaves, and in the husk of fruits. In the latter positions it forms a sheath to the vascular tissue (*fig.* 86, *c*), rendering the latter at once flexible and protected from injury. It appears highly probable, that in addition to these properties, woody fibre has the office of conveying fluids in certain directions; as, for example, up the stem from the roots, along the veins from the stem, and down the bark from the leaves. It is true that, from the impossibility of actually observing the march of fluids in parts so minute and easily injured as vegetable tissue, no one has been able to demonstrate this; yet one can hardly doubt that such is really its function, when we consider how rapidly the sap flows up the stem of a tree, which consists chiefly of woody fibre; and that, when coloured infusions are compelled to enter the system of a plant, they are uniformly found to pass to the very extremity of the veins, whither it would seem impossible that they should be conveyed, except by means of woody fibre.

§ 3.—*Vascular Tissue.*

Under this head is comprehended every form of tissue which does not belong to the cellular and the woody. The type of it may be considered the *spiral vessel*, from which the other forms probably are deviations produced by accidental circumstances.

A spiral vessel (*fig.* 85, *a*) is a cylinder, tapering to a cone at each end, composed of exceedingly thin membrane, in

the inside of which one or more fibres are rolled in a spiral manner, so closely

Fig. 85.

that the spires all touch each other. When at rest, it resembles a wire spring, and, like that contrivance, is so elastic, that it will contract, when extended by stretching the two ends.

The toughness of the fibre, of which a spiral vessel is formed, is quite extraordinary, when compared with its excessive fineness. If you pull the stalk of a Strawberry leaf asunder, gently, or the young shoot of a Dogwood, the spiral vessels will be unrolled in great numbers, resembling the threads of a spider's web; by stretching them gradually they may be broken, one after the other, till at last only two or three fibres remain; and they will be found tough enough to bear the weight of a considerable piece of the stem or leaf to which they belong.

Spiral vessels are generally seen by learners in an unrolled state, which is the most easy to obtain, but the worst calculated to give a correct idea of their real nature; for what notion can be formed of the original position of their parts by viewing a parcel of entangled silver threads, glittering in the light, as a mere object of curiosity? One of the best modes of seeing them is to take a piece of Asparagus, in the boiled state in which it is brought to table, and to tear it in pieces in water. By means of a little careful tearing and cleaning, you may extract from the pulp, which is cellular tissue, a quantity of fibrous bundles, which are in part woody fibre, and in part spiral vessels; the elasticity and disposition to unrol, in the latter, being destroyed by the boiling, they may be easily separated in an entire state, when their terminations and the true position of their internal fibre will be distinctly perceived.

Spiral vessels are confined to the veins of leaves, and of those parts which are modifications of leaves, such as sepals, petals, stamens, carpels, and fruit; and to certain places in the stem. In the stems of Exogens, they form the medullary sheath (see page 16 and fig. 13 c), from which they diverge into the leaves, &c. In Endogens they form the central part of every bundle of woody matter, and from these bundles pass into the veins of the leaves, which are mere external elongations of the bundles. They are absent from the bark of all plants (except Nepenthes), and are only found in the root of Endogens. In plants which never bear flowers, they are altogether wanting, except in the form of ducts; the nature of which will be explained presently.

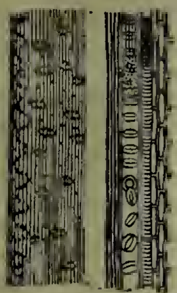
If a stem is cut across under water, air-bubbles form immediately at the mouths of the spiral vessels. If a thin longitudinal slice of live vegetable matter is viewed under similar circumstances, its spiral vessels will be seen dark and distended with air; submitted to the action of the air-pump, proofs are furnished of a similar nature; hence spiral vessels are considered respiratory organs, and the French call them *tracheæ.* Bischoff has analyzed the air they contain, and found it contain 6 or 7 per cent. more of oxygen than atmospheric air. From what source the additional oxygen is obtained is as yet unknown; but it may be conjectured to be produced by the decomposition of carbonic acid in the tissue that lies in the vicinity of the vessels. There are those, indeed, who insist upon the spiral vessels being intended for the conveyance of fluid. But with reference to this opinion, it is sufficient to remark, 1st, that these writers evidently confound ducts and dotted vessels with the spiral, which is a most important error; 2nd, that even if fluids are occasionally found in old spiral vessels, that may only show that they admit water through their sides, when their aëriferous functions are over; 3rd, that the close coils of fibre which line their inside, seem well contrived for hindering the escape of air, and the introduction of water; and, 4th, that there appears to be no provision for the conveyance of air through the central

parts of plants, if that office is not performed by the spiral vessels.

Ducts are organs having a great resemblance to spiral vessels, and are probably a mere modification of them; they are chiefly distinguished by their want of elasticity, and of the power of unrolling. Like the spiral vessels they consist of a very thin cylinder, terminating in conical extremities, and hav-

b b *c b a*

Fig. 86.



ing a fibre twisted, spirally in its inside; but the spires of the fibre are brittle, so that they snap when stretched, instead of unrolling. In the *closed duct* (*fig.* 86, *a*), the fibre is placed exactly as in the spiral vessel; in the *annular* (*fig.* 86, *b*), the spires seem broken into rings, which join at their extremities, and give the organ the appearance of a tube partially filled with rings lying irregularly in the inside; and in the *reticulated* (*fig.* 90 *d*), the spires of fibre touch, and grow together in so irregular a manner as to form a sort of netted bag, with very unequal meshes.

The closed duct is found principally in Acrogens, in which it represents the spiral vessel; the others are little known, except in the herbaceous stems of plants which grow with considerable rapidity. They occasionally occur in wood, especially of the Coniferous kind. One of the best plants to examine for the annular and reticulated duct, is the Garden Balsam, or the Touch-me-not (Impatiens), in whose stems they are abundant.

Their office seems to be to convey fluid at one period of their existence, whatever it may originally have been; for they are certainly filled with sap in such plants as those to which we have just referred. Considering their relation in structure to spiral vessels, one cannot avoid suspecting that to convey air was their original destination; but if so, this must have ceased soon after their first creation; for the thinness of their sides, and the very imperfect manner in which they are guarded internally by fibrous spires, are such that no resistance would be offered by them to the infiltration of fluid from the tissue that surrounds them.

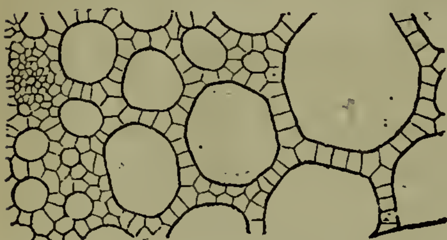
By what means vessels communicate is not very certain. Mr. Slack represents their extremities to be absorbed where they touch, the membrane disappearing, and the fibre only remaining in the form of a sort of grating placed across the aperture. Is this a general fact, or is it confined to special cases?

Many attempts have been made to determine the true functions of these and the other kinds of tissue by causing coloured infusions to ascend them; but the artificial and unnatural circumstances under which such experiments have been performed, the great difficulty of telling whether such minute organs are really coloured by matter that has introduced itself into their cavity, or are only apparently so in consequence of the colouring matter shining through their transparent sides, and more especially the impossibility of ascertaining that fluids do not rise through the *intercellular passages*, have rendered all such attempts so unsatisfactory that they are not worth describing here.

Intercellular passages are the spaces necessarily left between the sides of the vesicles or tubes of tissue when placed in contact. If those vesicles or tubes were regular polygons or prisms, they might be so fitted together that no spaces would be left between them; but being always irregular, and usually spheroids or true cylinders, they are, in fact, analogous to a heap of bladders, or bundles of straws packed together, between the component parts of which considerable spaces must necessarily be left. It is these which, under the name of intercellular passages, are supposed to assist materially in conveying the fluids of plants from one part to another. They are, therefore, not special organs, but only passages between other organs. Of the same nature are what are called *turpentine vessels*, *receptacles of oil*, *and air-cells*. The two first are mere cysts; the former fistular, the latter spheroidal, formed in tissue, into which the secretions of a plant are drained; the short irregular tubes in which turpentine lies in the bark of a Fir tree are an ex-

ample of the former: the numerous cavities containing essential oil, in the rind of an orange, of the latter. Air-cells (*fig.* 87) are cavities formed in the

Fig. 87.



leaf or stem, for the purpose of enabling a plant to float in water. They are built up with a degree of regularity which is most admirable: having their sides composed of cellular tissue in different forms, now round, now lengthened, now angular, according to the situation it occupies in the sides or angles of the cavity, and evidently contrived with the most careful foresight: those parts having forms adapted to stretching where any strain is likely to occur, and those being solid and unextensible where there is merely weight to sustain. Than these air-cells there is not one of all the works of the creation more richly deserving the attention of the philosopher, who seeks for illustrations of the design and skill of the divine Artificer of Nature. The leaf-stalk or stem of a floating Crowfoot, or the Duck-weed, obscure and insignificant weeds as they seem, exhibit an elaborate perfection of workmanship, employed merely to render such objects buoyant in water, infinitely beyond the most exquisite architecture of the most gorgeous temple in the universe.

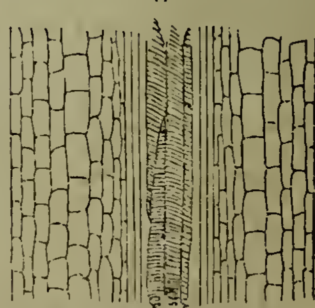
Different as are the various forms of tissue which have been now described, it is the opinion of some distinguished vegetable anatomists that they are all mere modifications of the vesicle or cellule; this is, in particular, the view lately taken of the subject by Mirbel. This distinguished botanist, in a most curious paper on Marchantia, to which allusion has been made on more than one occasion, asserts that he has seen common rounded cells of cellular tissue develope into long slender tubes, tapering into each end; that those, which originally have "membranous, thin, even, transparent, entirely colourless sides, gradually thicken, lose their transparency, and become marked all round, from end to end, with two parallel streaks, which are very close together, and traced in a spiral direction. Afterwards they enlarge, the streaks become slits, which cut the sides of each tube, from one end to the other, into two threads, whose circumvolutions separate, after the manner of the thread of a gun-worm." He also makes some observations upon changes of another kind, by means of which cellular tissue becomes converted into annular ducts.

It must be obvious, however, that observations of this kind, however carefully made and faithfully recorded, are so liable to error, in some of the details, that they require to be repeated by several independent observers before they can be received as positive facts. Even as the case now stands, a different interpretation might be put upon the appearances described by Mirbel himself, admitting them to be described correctly; and as at all events, for all practical purposes, it is indispensable that we should distinguish correctly the three principal kinds of elementary organs which have been here described, it is not desirable to dwell longer upon this part of the subject.

We shall, therefore, conclude the explanation of the structure and functions of tissue with representations of the relative position of the elementary organs in those cases in which their action is the most likely to come frequently under our consideration hereafter. In all the three following figures, *c* signifies cellular tissue, *dd* dotted ducts, *f* woody fibre, *s* spiral vessels, and *d* vascular ducts.

Fig. 88 is a plan of their position in the stalk of a leaf, showing in what

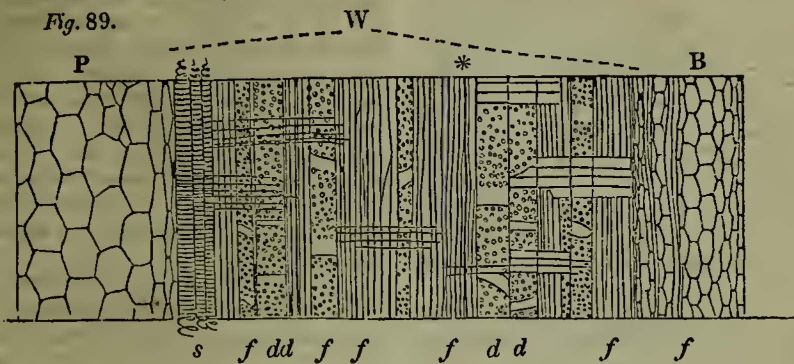
Fig. 88.



order they are respectively placed when the systems of the wood and bark become blended together.

Fig. 89 is a plan of the arrangement of the elementary organs in the branch of an Exogen two years old; P being the pith, W the wood, B the bark, * the limit where the wood or the bark of

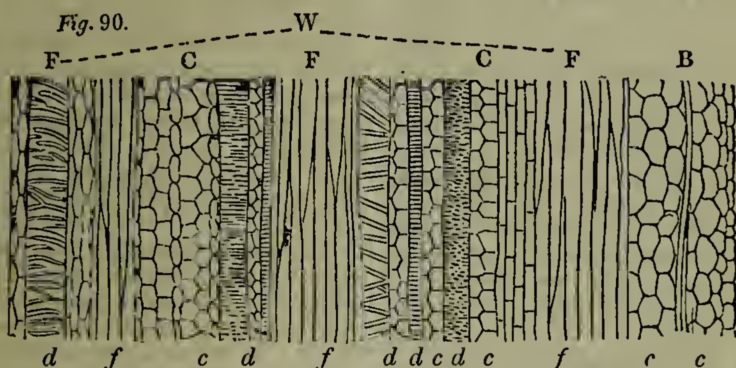
Fig. 89.



one year ceases and of a second begins, and the tissue lying in a horizontal direction across the wood being the muriform cells of the medullary processes.

Fig. 90 is a plan of the arrangement of the tissue in the stem of an Exogen: these details are taken from Von Martius' splendid work upon Palms; B is the cortical integument which answers

Fig. 90.



to the bark of an Exogen; W is the woody centre, consisting of bundles of fibro-vascular tissue marked F, and cellular substance marked C, analogous to the pith and medullary processes of an Exogen.

Chapter II.

General Considerations concerning the Nature of Plants, and the Means they have of performing their vital Actions.

Now that the reader is acquainted with the general nature of all the organs of plants, and that he understands the structure of those minute elementary parts by the united forces of which they are enabled to perform their functions, we may proceed to sketch out the latter in their principal outlines, here and there putting in the shadows, as a painter would say, for the sake of bringing certain objects more distinctly into view, but in all cases avoiding the minuter details; for which the inquirer is referred to works of a more extensive nature than the present.

In this department of the science, the difficulties which the philosopher has to overcome are of a very different character from those which may have embarrassed him in merely determining the organization of a plant. In the latter case good microscopes, manual dexterity in preparing the parts for examination, and sufficient patience for his task, are sure to bring the observer to conclusions, the general truth of which is often susceptible of exact demonstration; but when we come to consider the causes of vital phenomena and the manner in which

they are brought about, we have obstacles of quite another kind to overcome. There is not a function of vegetable life which is not performed, as it were, behind a screen; the parts which are the prime movers of every phenomenon are so minute as to escape our view until they have been killed for the purpose of microscopic examination; fixed to the soil, having scarcely any power of moving any one of its limbs, destitute of passions, or sensations, the visible expressions of which might lead us to the discovery of their invisible causes,—having the whole of its organic mechanism concealed beneath a skin which seems inert and is opaque,—and more especially having no actions which can be, with any exactness, compared to those with which we are necessarily acquainted from their taking place in our own bodies,—we are compelled to trust for all our notions of Vegetable Physiology to induction from data, about which, in many cases, there must always, from the nature of things, be some kind of uncertainty. For these reasons, a great diversity of opinion has existed among physiologists concerning many of the phenomena of vegetable life; multitudes of erroneous theories have obtained belief almost without question; and when an old notion has been shown to be erroneous, the world has willingly adopted another in its place, which, perhaps, has not been less unfounded. In the midst of the confusion attendant upon this state of things, a certain number of seeming truths have been elicited, about which there is daily less dispute; and by taking them as guides, or as tests of the truth of other opinions, the whole subject is assuming a state which becomes daily more satisfactory. What will be principally adverted to in the following pages are the best-known facts and most generally received opinions of the present day. Before, however, we proceed to a systematic consideration of the subject, it will be useful to dwell for a moment upon some of the general properties of vegetable matter, independently of the special attributes of the organs of plants.

§ 1.—*Extensibility.*

One of the most obvious circumstances connected with the growth of plants is the power which the tissue possesses of stretching,—or, in a word, its extensibility. We see a branch increase from a line to half an inch in diameter in the course of a year, and its surface still extending with the expansion of the matter enclosed within it; the tissue of the surface must, in this instance, have acquired many times its original dimensions. The leaf of a Lime-tree is formed as a little scale; in a fortnight after it once unfolds, it will grow, by the extension of its tissue, to a thousand times its original size; a similar occurrence takes place in the petals, the stamens, and all parts where development is rapid. It is true, indeed, that such cases of augmentation arise, in part, from the formation of fresh cellules amongst those which were first created, and that, consequently, an increase in bulk is not owing to extensibility alone; and this is to a great extent the case with bark. Still there can be no reason to doubt that the power of extensibility exists in a very considerable degree. Many cases of what is called irritability, for example, depend, as we shall presently see, upon tissue being stretched up to a certain point beyond which it cannot give way.

§ 2.—*Elasticity.*

The bending of wood, the waving of branches in the air, the springiness of cork, the flexibility of the cane, are abundant evidences of elasticity being also a common property of vegetable matter: indeed, it is from timber possessing this quality that it is so valuable to man.

§ 3.—*Contraction.*

A power of contraction is inseparable from elasticity, which, in fact, depends upon the capability of parts when stretched of resuming their original size with rapidity when the straining power is taken off. Independently, however, of this, it exists in many instances where it could not be suspected by the casual observer. Many cases of what is called irritability are more immediately owing to contraction; as in the stamens of Pellitory (Parietaria officinalis). In that plant the filaments, before the flower expands, are curved inwards and downwards, so that the anthers are inverted at the bottom of the calyx; the face of the filament consists of a lax and soft tissue, which is easily extensible;

their back is composed of a more compact and more rigid tissue; the latter is strained to the utmost in consequence of its forming the convexity of the curve, while the stamens are growing, till the segments of the calyx which keep the stamens down are unloosened: the moment this occurs, and the pressure is taken off, the tissue at the back of the filaments suddenly contracts, and the latter are bent outwards with violence; the anthers opening and scattering their pollen at the same time. Even this latter phenomenon is supposed to be caused by the contraction of the cells that form the case of the anther, which, simultaneously shrinking, exercise upon each other a strain which renders it necessary that something should give way; and as the tissue adheres more feebly at the suture of the anther than at any other part, it is there that the sides of the anther separate, and form an opening for the escape of the pollen. Other instances not less striking of the general power of contraction in tissue deserve to be mentioned. If you divide a stem of any common Spurge (Euphorbia), you will find the milky fluid in which that plant abounds run out of both wounds in whatever direction the pieces may be placed: here it is plain that the tissue is turgid with fluid, which keeps its sides in a state of extension; cutting through the tissue takes off the pressure upon its sides, which accordingly contract and squeeze out the fluid within them. With reference to this phenomenon, De Candolle justly observes, that if the fluid was emitted in consequence of an impulse from below upwards, or from above downwards, it would only run out at one of the two wounded ends; and that if it was discharged merely by virtue of its gravity, it would only flow out when the mouths of the wounded tissue were turned downwards; neither of which cases occurs. In fact, a curious experiment of Van Marum and Humboldt has shown, by something like a demonstration, that it must be contractibility that causes this phenomenon; it is known that animals killed by electricity lose their powers of contraction, and those observers found that Euphorbias, destroyed by that agent, equally lost the power of discharging their milk.

§ 4.—*Hygrometrical Properties.*

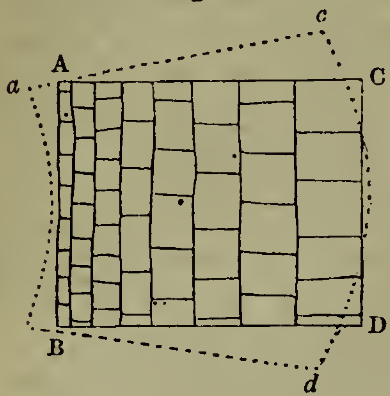
The hygrometrical properties of living vegetable matter,—that is to say, the power of abstracting moisture from surrounding media, is one of great activity and importance in relation to most vital phenomena. De Candolle has well remarked, that this power is most energetic in the parts which are the least charged with foreign substances, and *vice versâ.* Thus it is extremely active in the newly-formed portions of any plant, especially at the points of the root, where the fluid of the soil has chiefly to be sucked up—in the newly-formed wood —and in but a very slight degree in bark, which, in consequence of its being the descending channel of the elaborated sap, is filled with earthy and other matters. Owing, no doubt, to particular organic differences, the hygrometrical powers of particular parts act in very different ways; most capsules burst, and the beards of the Geranium or the Oat curl up, in dry weather; but those of Epilobium and the Fig Marigold (Mesembryanthemum), and most other plants, contract in dry weather, opening only in wet. The latter forms a beautiful object in some of the larger species, which are occasionally brought from the Cape of Good Hope as curiosities. When dry and closed, they resemble an almost-shapeless lump of wood; but placed in warm water they gradually unfold at the point, and by degrees assume the appearance of a star, which, when they are fully expanded, assumes the most perfect symmetry and regularity.

The Rose of Jericho, and the curious Lycopodium of Peru, are other instances of parts unfolding by the application of moisture. These plants are dried up by the burning sun and parching air to which they are periodically exposed, often are detached from the spot on which their slender roots had fixed them, curl up by the contraction of their branches into a round ball, which is blown about by the wind, and becomes the sport of storms. But the moment they are exposed to moisture, their hygrometrical properties cause them to unfold; they suddenly revive, and fix themselves by their own weight to the spot where they receive the influence of moisture.

The cause of the different effects of

moisture upon different plants, in regard to their contracting or expanding, may, perhaps, be understood by reference to the following figure.

Fig. 91.



Let the figure A B C D represent a section of the tissue of any vegetable body. Let the line A B represent the outside, and C D the inside of, we will suppose, the sides of a capsule, which only opens in wet weather, or upon the application of moisture. The cells next the inside C D being larger and thinner sided than those next the outside A B, will absorb moisture with the greatest rapidity and force, and becoming gradually distended will lengthen by degrees; but this will be resisted by the small, thick-sided, and consequently less permeable cells at A B, and the result will be, that as the cells C D lengthen, they will be pulled towards *c d*, while A B will at the same time be forced in the direction *a b* by the general distention of the tissue from C to A, and from D to B; and thus the opening of the capsule will be effected. Reverse the structure, and an opposite effect will be the result; and thus we may understand how it is owing to differences of an organic nature that some parts will unfold and others contract upon the application of moisture externally.

§ 5.—*Endosmose.*

The explanation just offered is that by which Dutrochet accounts for certain cases of what has been incorrectly called irritability. He ascertained by some ingenious experiments, that if liquids of unequal density are separated by animal or vegetable membrane, the thinner fluid will pass through the membrane towards the denser. This may be easily shown by a very simple contrivance: take a common half-ounce phial, the bottom of which has been ground off, and tie a piece of bladder tightly over the opening thus effected. Fill it with mucilage, such as thin gum arabic and water, and half immerse it in water. The denser fluid in the phial will slowly attract the water through the membrane, and the contents of the phial will run over. Reverse the experiment by filling such a phial with water, and plunge the lower end into milk, or sugar and water, or mucilage, and the water will pass out of the phial through the bladder, as will be shown by the water in the phial sinking. This phenomenon Dutrochet called *Endosmose.*

The whole surface of a plant may be considered as a series of bladders, in a state of endosmose—that is to say, as containing fluid of a more dense nature than the aqueous particles that surround them in the atmosphere or in the soil. A plant is, therefore, a sort of endosmometric apparatus, which is incessantly in action, so long as it retains the vital principle, and the force of which is regulated by temperature. This peculiar absorbing power is by no means confined to the surface of a plant; on the contrary, it exists between the internal bladders of cellular tissue and the other elementary organs, wherever there is a difference in the density of the fluid in contiguous cavities; and Dutrochet conceives, with great appearance of truth, that the circulation, as it is called, of the sap, and the distention of one part more than others—or, in other words, the power which some parts have of attracting sap to themselves from the neighbouring tissue, depends essentially upon the phenomenon of endosmose. An instance or two of this will suffice for the present, as we shall return to the subject hereafter. When buds unfold, and grow in the spring, the cells part with some of their water by evaporation; the fluid that remains becomes denser than in those cells which, being more internal, are unable to perspire, and the action of endosmose, which is immediately established, fills the external cells at the expense of the internal ones, which, in their turn, abstract fluid from those which are still more interior. Again, a carpel is fertilized, and is to become a Plum; its cells gradually form in their interior

a fluid of a denser nature than the sap which is near them, and attract it by virtue of endosmose. The circulating system of the plant keeps perpetually supplying the loss thus occasioned, and the plum is thus enabled to become the succulent body which we see. Perhaps the most direct illustration of the effects of endosmose in vegetation may be obtained from the Balsam, a common plant, which any one may procure for experiment. Dutrochet gives an interesting account of his observations upon it, of which the following is a short abstract :—It is well known that the valves of the capsule of the Balsam, when ripe, separate from each other, and that each rolls up spirally, *inwards* —that is to say, that their convexity is outward, or on the side of the cuticle. If you straighten them, they regain their curved state spontaneously and smartly, when they are left to themselves. If they are thrown into water, they curve with greater force than ever; but if they are allowed to become half dry, they fall into a flaccid state, and lose their elasticity, which is however restored by placing them again in water. This shows that the presence of water in the tissue of the valves is at least one of the causes of their rolling up. Upon examining the tissue of a valve, it will be found composed of little bladders, the largest of which are next the cuticle, and the smallest next the inside, gradually diminishing in size from without inwards (or being as represented at *fig.* 91, taking C D for the outside). Considering what the effects of endosmose are in other cases, it may be conceived that the violent incurvation of the valves of the Balsam may be owing to this phenomenon acting principally upon the external vesicles, distending them with fluid attracted from the rising sap, and giving them, when thus distended, a curve outwards, in consequence of the resistance of the base and apex of the capsule; and that, whenever the valves become so turgid as to burst from the extremities of the capsule, which keep them in their place, they will immediately lengthen and curve inwards. To ascertain how far this may be true, take a little syrup and water, which shall be denser than the fluid in the cells of the Balsam-valves; place the latter in it, and they will first straighten, then curve backwards, and at last roll up in the opposite direction from that which is natural to them. This arises from the syrup abstracting the thinner fluid from the bladders of the tissue of the valve, when the valve rolls backward, because the bladders next the outside, being the largest, lose the greatest proportion of their contents, and moreover have the smallest quantity of solid matter within them; in consequence of which they not only return to their original size, but actually contract, and the valve rolls backwards. If these same valves are again placed in water, they attract it by the renewed action of endosmose, first straighten again, and finally curl inwards, resuming their natural state. Dutrochet says he repeated this nine times in five hours, after which they ceased to curve inwards when plunged in water; which he ascribes to their having, by such frequent exposure to the action of the syrup, been gradually robbed of their dense contents. But when placed in syrup, they still continued to roll backwards with an increased energy, because the fluid they still contained had gradually become less dense by the repeated dilutions with water which it had experienced. If a thin slice of the valve of a Balsam be placed under a microscope, the whole of this mechanism may be distinctly beheld. The cells will be seen to diminish rapidly in diameter, especially the larger ones, in consequence of their being emptied, and the valve will gradually reverse the direction of its curve.

Endosmose must be considered, then, as a phenomenon, to the effects of which the greatest importance is to be attached. This will be shown more completely hereafter.

§ 6. *Irritability.*

The various powers of which an explanation has thus been given, however important they may be, do not of themselves account for any one of the phenomena of vegetation. All of them may and, indeed, do, exist in dead matter; the living principle is still wanting to set them in action, to regulate their reciprocal efforts, and to modify them according to the special constitution of different plants.

It would be a waste of time to speculate upon what this living principle may be; and we should have no ambition to invade the province of the psychologist, unless we thought ourselves

likely to discover something more than the subtleties of metaphysicians have yet elucidated. It is sufficient for the world to know—what, indeed, is all that it can know—that the principle of life is a something which is dispersed through all organic matter, and which not only sets the organic elements in action, but preserves them from entering into that state which quickly leads to their return to inorganic substances.

It is under the names of *irritability*, *excitability*, and *sensibility*, that the more immediate effects of the vital principle have been discussed by physiologists. For all practical purposes these may be considered as the same; for even sensibility, by which is meant something analogous to sensation in animals, is not, in vegetable physiology, distinguishable from the two others.

There are those, indeed, who have endeavoured to show that sensation, properly so called, exists in plants; and they have founded their opinions upon certain curious phenomena. The singular power of motion, when touched, for which the Sensitive-plant is so celebrated, has been supposed to be an extreme instance of this; and Dutrochet has even attempted to show that the nervous particles, in which sensation specially resides, are visible to the eye. Great numbers of little green balls of amylaceous or resinous matter are discoverable by the microscope sticking to the tissue of most plants. In the Sensitive, at a little swelling at the base of the leaf-stalk, in which the greatest degree of motion resides, they are particularly abundant; and what is extremely curious, these balls, or granules, are found to be affected by certain chemical agents in the same way as the nervous particles, or what are so considered, of certain molluscs. Boiled for a short time in nitric acid, they become opaque, and regain their transparency upon being plunged in a solution of caustic potash;—but the same granules exist in an equal degree in plants which have nothing approaching to sensation; so that their function cannot be admitted to have anything to do with it. Secondly, poisons have been found by Macaire and Marcet of Geneva to act in the same way upon plants as upon animals; corrosive poisons stiffening the organs as if they produced a sort of vegetable inflammation; narcotic poisons relaxing the whole system, and causing something that has been considered analagous to stupefaction. Hence it has been concluded, that there must be something analogous to *the scattered elements of a nervous system* in plants. Brachet, a French physiologist, has even gone further, and has very recently endeavoured to prove that the pith is the seat of the nervous system in plants, and that the medullary rays are nervous branches. The statements of this writer do not deserve serious refutation; and with regard to the effects of poisons, I do not know that it is necessary to go so far as to admit the presence of a nervous system, in order to account for their effects, especially where there is so much reason to object to the opinion. Upon this subject we cannot do better than quote the words of De Candolle, the celebrated Professor at Geneva:—"The nervous system, which is very evident and distinct from all others in animals of the upper classes, gradually tends to divide; and finally one is forced to admit, that in zoophytes the nervous matter is diffused, as it were, throughout the whole body; so that the latter possess a kind of universal sensibility, without there being any where a nervous system distinct from the tissue. Hence, say they, we arrive at the vegetable kingdom, where the nervous system is incorporated with the whole tissue; but if this conclusion is to have any probability, it must be shown that the plants which have the greatest resemblance to zoophytes in structure are also those in which the symptoms of sensation are the most evident; which is not the case. All the plants in which it has been thought that it might be perceived, are at the other end of the scale of organization; and consequently the analogy deduced from the animal kingdom does not lead, with anything like force, to the admission of sensation in the vegetable kingdom. Let it also be remarked, that all the most constant and most common phenomena of vegetable life seem to be intimately connected with, and even are necessary consequences of, the absence of spontaneous motion. But spontaneous motion, wherever it exists, is evidently the result of sensation; whence one has a right to conclude, that where the former is wanting, the latter is wanting also."

It is to irritability that we are disposed to refer all the powers which the

organs of plants possess of performing their functions. We know that, in the absence of all stimulants, they are incapable of action. Under this name we would include, in particular, light, heat, and moisture; for all these being abstracted, plants are incapable of maintaining their existence. It is not often, however, that the effects of these agents are manifested by visible signs; it is only in cases where irritability is in excess that we perceive them. The leaves and flowers of all plants are excited by the stimulus of light; but it is only when the petals close or unfold, and that leaves droop or raise themselves erect, that this phenomenon strikes us—that is, when the irritability is excessive.

We feel the more justified in considering what are called cases of vegetable irritability to be merely the vital principle in a state of concentrated action, from this circumstance—that no one has yet been able to throw the smallest light upon the cause of the motions of plants, or to give us anything beyond an explanation of the mechanical means by which the vital principle is enabled to take effect; for we feel quite justified in asserting, that Dutrochet, after all his patient investigations and ingenious experiments, has not advanced one step beyond this.

For the sake, however, of those who may be interested in pursuing such an inquiry, we will mention a few cases which may be easily witnessed of vegetable irritability in excess.

If you touch the surface of the branches of a Lettuce plant in flower, milk will be immediately emitted by the cuticle at the place where it is touched. Here it is supposed that the cellular tissue below the cuticle is in a high state of irritability, and by its contraction forces the milk out through the stomates.

If you touch the filaments of a Kalmia or a Barberry with the point of a pin, near their base, in the inside, they will curve forward, and strike their anthers against the stigma.

The Monkey-flower (Mimulus) has a stigma with two broad thin lips, which stand apart in fine warm weather. Touch them at that time with a bristle, or any such thing, and they collapse suddenly with considerable force.

A plant found in Carolina, called Venus' Fly-trap (Dionâea), has long bristles proceeding from the edge of its leaves, and curving inwards like the teeth of a rat-trap. Touch the surface of the upper side of the leaf, the sides will collapse, and the teeth will close up with such force that it is difficult to separate them again.

A very common plant in the greenhouses of curious persons in the Stylidium, many species of which inhabit New Holland; it has a long column, composed of stamens and style united, springing from the centre of its flower: when at rest this column bends down over one side of the corolla, as if it wished to conceal itself; touch it, however, ever so lightly, and it starts up with a jerk, and rapidly swings over to the opposite side of the flower.

The Sensitive plant has its leaves divided into a great number of leaflets, which spread flat in the sunshine, and seem as quiet as other leaves; but only touch one of the leaflets, and the whole system of the leaf will be irritated; all the leaflets will rapidly collapse, one after the other, till at last the impulse is communicated to the base of the leaf-stalk, which immediately curves downwards. After a time it rises again, the leaflets unfold, and the leaf resumes its original appearance and direction.

§ 7.—*External Agents.*

Light, heat, and water are the external agents which, acting upon the vital principle, set all the machinery of vegetation in motion. No one of these causes will by itself produce any effect, although their combined action is of the most powerful kind.

Light, as we shall hereafter see, causes the decomposition of carbonic acid, fixing the carbon in the interior of tissue, and thus solidifying the most delicate parts, or altering the chemical nature of others; it is the grand cause of the varied colours of vegetation, and may be considered as being in part what produces a motion of the fluids. In its absence plants are weak and sickly, and soon perish.

Heat, by drying the atmosphere, produces evaporation, which is one of the great means by which the crude fluids become inspissated and altered in their nature; it causes the expansion of the gases which plants contain, distends their tissue, and renders the latter more capable of performing its

contractile and hygrometrical functions.

Water relaxes all the parts, dissolves the soluble matters which are laid up in a plant in a state of torpidity, and softens the tissue till it is capable of receiving the influence of temperature. It is, moreover, the medium by which the nutritious principles that are deposited in the earth are absorbed by the roots, and conveyed from one part of the system to another.

To sum up, in few words, all that has thus far been stated, it is light, heat, and water, acting in concert upon an irritable membrane, which enable plants, by virtue of their extensibility, elasticity, and hygrometrical powers, to perform the phenomena of contraction and endosmose, by means of which they absorb and digest their food, circulate their fluids, develope their organs, increase in size, and reproduce themselves.

What are the more immediate causes of the principal vital phenomena will be explained, as far as we at present understand them, in succeeding chapters.

CHAPTER III.

Of the Food of Plants.

There are those who have insisted that pure water is the food of plants; others have believed that plants have the power of selecting their food from among the various soluble matters surrounding their roots; and others, again, have declared that the air is alone sufficient to maintain a plant in health. These opinions, founded upon imperfect or ill-conducted experiments, are none of them exactly correct; although they each have a certain quantity of truth. The fact seems to be, that what may be called more particularly the food of plants, because it is that without which they cannot exist, is atmospheric air and water, in which carbonic acid is dissolved; that this alone is sufficient for their support; but that, under natural circumstances, they receive into their system a great variety of other substances dissolved in water; apparently not possessing any power of refusing to absorb whatever soluble matter may be offered to them, whether it be nutritious or deleterious.

We shall not occupy our pages with a description of the proofs by means of which modern chemists have shown the fallacy of the old experiments to prove that pure water is the food of plants; nor is it worth entering into a discussion of the causes of the errors of another nature which have led to the adoption of the opinions that plants can *select* their food from the soil. All that we can pretend to do, is to show upon what evidence the doctrines we state to be now received are based.

It is well known that pure water, as it is furnished by distillation, does not exist in nature; but that it is constantly mixed with earthy, saline, and gaseous matters, which vary in proportion according to the circumstances under which the water is impregnated with them; such water as this is necessarily what is offered to plants as their food. From the decomposition of the various organic substances which are buried in the soil results a considerable formation of carbonic acid,—a principle readily soluble in water, and consequently forming a considerable part of all the fluid introduced into the roots of a plant. The saline and earthy matters which find their way into the system are gradually deposited, almost unchanged, in those parts where the water in which they are dissolved evaporates; namely, in the leaves or the bark, or in some other part of the surface. But the atmospheric air, water, and carbonic acid become decomposed, and their elements, recombining in new proportions, form the materials for new parts, and the gum, fecula, sugar, azotic products, and other immediate principles of the vegetable kingdom.

If the roots of a plant are placed in a close vessel, in distilled water, from which carbonic acid has been carefully expelled, the plant may increase a little in size, in consequence of the decomposition of the water and the combination of its elements with the vegetable system; but it is only when carbonic acid is added that the plant acquires its natural vigour and rate of growth.

It is only in the state of carbonic acid that carbon can enter into the system of a plant; the former is easily decomposed, the oxygen is liberated, and the carbon remains fixed. But if a plant is placed in solid carbon, and you water it with distilled water, it might as well be planted in powdered glass, until the carbon begins to com-

bine with the oxygen of the air, and to form carbonic acid. Sir Humphry Davy placed a plant of Mint in water mixed with carbon, in a state of impalpable powder, and he found that not a particle could enter the roots. If we look to the effects of manures, we shall find that in most cases, except when their object is to alter the state of the soil mechanically, or to act as stimulants, as is probably the case with sulphate of iron, their energy is in proportion to their capability of forming carbonic acid. Yeast, for instance, which is one of the most active manures we have, is so from possessing, beyond all other substances, the power of exciting fermentation, and thus of causing the formation of carbonic acid among the vegetable matter which lies buried in the soil.

While, however, all experiments combine to prove that carbonic acid is the most essential of the elements upon which plants are nourished, it is necessary that the student should be aware that other species of matter are constantly taken into the system, and probably, therefore contribute to their nutrition.

Water is one of these. Although we know that a very large proportion of all the water absorbed by a plant is lost again by evaporation, yet the experiments of Theodore de Saussure have shown that a portion of it is actually solidified. He found that when plants are grown in a close vessel, in an artificial atmosphere, containing a little carbonic acid, the weight which the plant acquired in a given time was augmented, not only by the quantity of carbon produced by the decomposition of carbonic acid, but to a much more considerable extent, which could only be ascribed to its having fixed a considerable quantity of water; thus plants of Vinca, which, in a vessel without carbonic acid, had gained $1\frac{3}{4}$ grain from water, acquired $5\frac{6}{10}$, when they were at the same time able to procure carbon. The same excellent observer has computed, that if we calculate with the utmost care all the weight which a plant can gain either by fixing carbon, or by depositing earthy, saline, alkaline, and metallic matter which they borrow from the soil, or by respiring oxygen, or from the soluble matter of soil, we shall not be able to account for more than a twentieth part of the real weight of such a plant. The other nineteen-twentieths must, therefore, be fixed water. Whatever errors there may be in calculations of this nature, there cannot be a doubt that they are correct to so considerable an extent as to oblige us to admit that water forms a considerable part of the solid tissue of plants; so that it would appear that, like minerals, plants have a water of crystallization independently of their water of vegetation.

As it has been pretty well made out that all the oxygen given off by plants is produced by the decomposition of carbonic acid, and as no one has ever been able to detect the emission of hydrogen by any plants except Mushrooms, it is inferred that, if the water which is consumed by plants is ever decomposed, it is in the formation of the various secretions which contain more oxygen (acids), or more hydrogen (oils), than water; but as the greater part of vegetable substances, such as gum, sugar, fecula, &c., contain oxygen and hydrogen in the same proportions as water, it can hardly be doubted that the greater part is undecomposed and simply fixed.

It was formerly thought that nitrogen, or azote, has nothing to do with the nutrition of plants, and that in those cases where it was met with it was merely in a state of separation from the atmospheric air which had been inhaled and deprived of its oxygen and carbonic acid. But its constant presence in combination with the tissue of Mushrooms and of Cruciferous plants, in gluten, and what chemists call vegetable albumen, and also in vegetable alkalies, seems a sufficiently strong proof of its contributing, in some way or other, to the nutrition of the vegetable system.

We might stop here in explaining the nature of the food of plants, if it were not for the great quantity of metallic, earthy, and other matters which are taken up by them from the soil, and afterwards deposited in their tissue; matters which possibly do not contribute to their nutrition, but about the real nature of whose action we have no evidence.

One of the most remarkable of these is silex, which is secreted by certain plants in prodigious quantity. All Grasses abound in it; usually it fixes itself in their cuticle; but in the Bamboo it is also deposited in considerable

quantity in their hollow joints under the form of the substance called Tabasheer. The skin of the Rattan Palm abounds so much in silex that it will strike fire with a piece of steel; the same substance exists in Teak and other kinds of wood, to which it gives a peculiarly gritty texture; and in the genus Equisetum, or Horsetail, one species of which is used for polishing wood, in consequence of the whole surface being composed of compact silicious particles. It was once thought that silex must be actually formed by the action of the vital principle of vegetation; but Berzelius has proved that newly-forming silex is soluble in water, and consequently it is more probable, as has, indeed, been recently proved, that it is in a state of solution that it enters the system, and is afterwards separated from the water. Considering the immense quantity of water that passes through a plant in the course of its growth, there is no difficulty in conceiving the possibility of the largest amount of silex which is ever met with in vegetation originating in this way; but there is still one circumstance to be accounted for. If we grow a Pea and a grain of Wheat in the same soil, the plant which results from the latter will abound in silex, while that from the former will not. Now we have no reason to suppose that these two species have any special power of selecting their food, and that the silex passes freely into the one while it is stopped by filtration in the other case: on the contrary, all that we know of the functions of roots leads us to believe that both absorb the silex equally. What then becomes of it in the Pea? This is a question still to answer.

Lime, and many of its salts, especially the sulphate and phosphate, magnesia, potash, soda, sulphur, phosphorus, several metals, and a number of other species of matter, occur in plants, in greater or less abundance, all evidently taken up from the soil. Of these soda is the best known and most abundant, existing to the amount of as much as fifty-five per cent. in the state of a carbonate in the ashes of Salsola sativa in Sicily (*Fée*); and copper the least suspected and most curious. This metal is stated by Sarzeau, according to De Candolle, to form eight parts in a million in coffee, and about four parts and a half in a million in wheat; whence this chemist has calculated that we annually import into Europe more than 1200lbs. weight of copper in our coffee, and that the French annually consume nearly 8000lbs. in their bread.—(*Journal de Pharmacie*, 1830, p. 505.)

By what means plants are enabled to procure the various kinds of matter which we have seen to enter into their system, is the next subject of consideration. The roots are no doubt the organs which are specially destined for this office; it is they which are placed in the most favourable situation for such a purpose; and which, from their organization and mode of growth, seem also to be the best adapted to it. When young they consist of a sheath of thin and exceedingly hygrometrical cellular tissue (*fig.* 92, *a a*), surrounding a

Fig. 92.

bundle of woody and vascular matter, *b b*. At this period they contain mucilaginous matter, which enables them to attract fluids from the soil that surrounds them, and having obtained it, they send it upwards into the general system. The power of suction which is thus given to them is incessantly in action, and with a force that is almost incredible, considering the smallness of the means by which it is effected this will be evident when it is seen with what force the sap of a plant is impelled upwards at certain periods of the year (*see* Chapter VI.), and when it is mentioned that Hales found a Sunflower, three feet high, lose twenty ounces of water daily, to supply which the roots must have obtained from the soil not twenty, but thirty ounces of fluid daily; for, according to Senebier, a plant retains, on the average, one-third part of all the water that enters its system, and fixes it in a solid form.

It is only, however, in their youngest state that the roots have this extraordinary power; as soon as their tissue becomes charged with earthy matter, deposited by the entering fluids in their passage from the soil, their power of suction is diminished, and seems in the end to cease altogether. Thus, if you take a carrot and place the point

of its root in water, it will suck up the moisture as well as if the whole root were immersed; and on the other hand, if you place the whole root in water, except the point or newly-formed part, it will not suck up the fluid in any considerable quantity. For this reason the young tips of the roots are of the utmost importance to a plant, and its well-being depends in a greater degree upon their preservation than upon any other circumstance. In consequence of the great impoitance of the tips of the roots, they have received the special name of *spongioles* or *spongelets*, and are sometimes spoken of as if they were really distinct organs; they are, however, nothing more than the young and tender extremities of the roots. As fast as they solidify, they lose their power, and cease to be spongelets; but as the roots, when growing, are incessantly forming new matter at their points, spongelets are perpetually present, notwithstanding that they are perpetually disappearing.

If we take this circumstance in connexion with the fact, that, in general, *roots* do not *lengthen* except by the addition of new matter to their points, we shall find that the function of feeding in plants is one of the most beautiful instances of contrivance in the whole vegetable kingdom. Growing, as they do, in a solid resisting medium, if they lengthened by a general extension of previously formed parts, they would be constantly interfered with by the uncertain nature of the earth in which they are developed; as the degree of resistance offered by soil to any solid passing through it, is, from its very nature, most unequal and uncertain, it would be impossible that the force with which the roots push forward could be ever proportioned to the resistance opposed to their advance, and, consequently, they would become so twisted and knotted, that their fluids would no longer circulate through them with the regularity required by the exigencies of the stem and leaves. And if they absorbed fluid from every part of their surface, the soil round a tree must become so dried up, that, as the roots cannot stir from the place where they are first formed, they would speedily perish from the consequences of their own action upon the earth that surrounds them. Providence has, however, so contrived them, that they are exposed to no such effects. Increasing by constant additions of young matter to their delicate points, they are able to insinuate themselves between the solid particles of the soil with the greatest facility, in which they are much assisted by the softness and pliability of their new-born tissue; thus we find them able to pierce the little cracks in a stone till they have passed beyond it, when their power of expansion will often enable them to burst it; and we often see them insinuating themselves into the crevices of walls, and penetrating solid masses of brickwork. If, however, the rootlets insinuate themselves into a crevice to which there is no outlet, they are merely arrested in their advance; and the facility with which they subdivide into other branches, enables them immediately to counteract the inconvenience produced by their stoppage, by emitting from their sides a number of little sprouts, each of which will advance into the soil in search of moisture. The same property prevents their exhausting the soil of the moisture that surrounds them, for they are all their lives long removing from the exhausted point to new and untouched soil; and this so effectually, that animals, with their powers of movement to aid them, are not better able to roam in search of fresh pastures, than the seemingly motionless roots are to seek incessantly for new feeding places. Some plants will send out their roots, under particular circumstances, to great distances in search of food; and their length will be amazingly disproportionate to the height of their stems. The Lucerne plant has a stem about two feet high; its roots have been taken from below the face of the escarpment of a sand-pit, as much as thirty feet in length; so that many of the little leaves had to be supplied by a living well three hundred and sixty times deeper than themselves. Powerful and important as the action of the roots must be, we must not suppose, on that account, that it is the sole medium by which nutritive matter passes into the system of a plant. Orchideous plants, and certain species of the Fig, have been suspended in the air, and they have continued to live, although their roots were destroyed; a species of Tillandsia is tied to the iron balconies of the houses in Buenos Ayres, and there it

lives and flowers; the Dodder clings round the stems of the Heath and Furze, and grows, flowers, and fruits during the greater part of its life without any communication with the soil; Misletoe has been made to sprout upon the surface of a cannon-ball; and other instances might be mentioned in which plants have grown without roots. If plants which have withered are syringed, they recover their freshness; and if the atmosphere of a badly managed greenhouse is saturated with moisture, the starved and dying plants recover. In all these cases it seems impossible to doubt that a certain quantity of moisture, and consequently of food, is absorbed by the surface of a plant, independently of roots; for we cannot ascribe all the cases just referred to, to the prevention of evaporation. Nor, indeed, does one see why we should; for any soft and succulent tissue is, as we have seen, capable of absorbing moisture through its sides in a greater or less degree, and such tissue exists on the bark and leaves of all plants. It must, however, be remembered, that whatever power we may ascribe to the leaves and stems of plants of keeping up the nutrition of the system in the absence of roots, yet that their power is as nothing compared with the efficiency of the roots themselves.

If, then, it is by the roots that plants are enabled to feed, and if it is more especially by their young and tender points, the importance of preserving those delicate organs must be obvious, while the mischief that will of necessity result from their mutilation or destruction will be readily appreciated; for although they may be renewed when destroyed, yet their replacement is a slow operation, and, in many species, is performed with difficulty, except under very favourable circumstances. The reader who is acquainted with gardening or planting will not fail to perceive the immense importance of these considerations as connected with transplanting trees; and that the violence and carelessness with which plants are frequently torn out of one place and thrust into another, are anything but calculated to ensure a successful result.

Chapter IV.

Of Digestion; or the means by which the crude Sap is converted into the peculiar secretions of Plants.

When the food of a plant enters the roots it passes upwards, undergoing some kind of chemical change, and dissolving whatever soluble matters it meets with in its course; so that, without having been exposed to any of those conditions by which it is ultimately and principally affected, it is considerably altered from its original nature before it reaches the leaves. If the trunk of a Birch tree be tapped in the spring, near the ground, it will discharge in great abundance a whitish limpid fluid, which is the rising sap; but if the sap be obtained from an aperture five or six feet higher, it will be perceptibly astringent; and at a higher point still, its difference from that near the root will be still more apparent.

It has already been remarked, that a portion of the water which plants suck up, combines with the tissue, and enters into the general constitution, where it becomes fixed, as the water of crystallization in minerals. This apparently takes place in the course of the ascent of the sap, before the latter reaches the leaves and becomes exposed to that sort of decomposition and alteration which is here called digestion, and with the phenomena attendant upon which we are best acquainted. Under what influences, except that of the vital principle, a decomposition of the sap takes place before it reaches the leaves, we are ignorant. But when it has reached the leaves, and thus becomes exposed to the effect of light, its action is less removed from our powers of observation; and physiologists have succeeded in ascertaining, to a great extent, the exact nature of the changes it undergoes.

What we find it most necessary to insist upon in this place, are the three following axioms, to which the experiments of careful observers and skilful reasoners have led:—1. *The quantity of water lost to a plant by evaporation, and its power of absorption from the soil, is in proportion to the quantity of light.* 2. *Light causes a decomposition of the carbonic acid of vegetation, and consequently, by solidifying the tissue, renders the parts most*

exposed to it the hardest. 3. *The digestion of plants chiefly consists in a loss of water by evaporation, and in an acquisition of carbon, by the decomposition of carbonic acid.*

That the quantity of water lost to a plant by evaporation is in proportion to the quantity of light is easily proved by the following experiment, mentioned by De Candolle:—"If you select three plants in leaf, of the same species, of the same size, and of the same strength, and place them in close vessels, one in total darkness, the other in the diffused light of day, and the third in the sunshine, it will be found that the first pumps up very little water, the second much more, and the third a great deal more than either. These results vary according to species and circumstances; but it uniformly happens that plants in the sun absorb more than those in diffused light, and the latter more than those in darkness; the last, however, pumping up something. If, again, we take three similar plants, and, preventing their absorption by the roots, after weighing them carefully, place them in three similar situations, we shall find that that exposed to the sun has lost a great quantity of water, that in common daylight a less amount, and that which was in total darkness almost nothing." Hence it may seem proved, that the action of solar light is the great exciting cause of suction at the one end, and of evaporation at the other end of a plant; and that, in the night-time, plants gain weight, while they lose it in the day-time. It is not, however, clear, that, to speak rigorously, although we may talk of light as being the sole cause of these phenomena, it is not rather the dryness of the atmosphere, caused by the heat of sunlight, as compared with the moisture of the air in the absence of the sun. Thus, plants in a dry sitting-room, to which the sun has no access, undoubtedly perspire by their leaves, and absorb by their roots, more than if they were exposed to the sun in a moister atmosphere.

Whatever doubt there may be concerning the precise causes of evaporations, there can be none whatever as to the power which sunlight has to cause the decomposition of carbonic acid, the fixing of the carbon, and the giving out of oxygen.

"If," says De Candolle, "two plants are exposed, one to darkness and the other to the sun, in close vessels, and in an atmosphere containing a known quantity of carbonic acid, and are removed at the end of twelve hours, we shall find that the first has diminished neither the quantity of oxygen nor of carbonic acid; and that in the second, on the contrary, the quantity of carbonic acid has diminished, while the quantity of free oxygen has increased in the same proportion. Or if we place two similar plants in closed vessels in the sun, the one in a vessel containing no carbonic acid, and the other in air which contains a known quantity of it, we shall find that the air in the first vessel has undergone no change, while that in the second will indicate an increase of oxygen proportioned to the quantity of carbonic acid which has disappeared; and if the experiment is conducted with sufficient care, we shall discover that the plant in question has gained a proportionable quantity of carbon. Therefore, the carbonic acid which has disappeared has given its oxygen to the air and its carbon to the plant, and this has been produced solely by the action of solar light."

However varied experiments may be, they all lead to the same result, and compel us to acknowledge the great importance of light to plants, in enabling them to digest the crude matter which they gain from the soil. In fact, there is nothing of which we have any certain knowledge that interferes with these conclusions. We see in practice that the more plants are exposed to light when growing naturally, the deeper is their green, the more robust their appearance, and the greater the abundance of their odours or resins; and we know that all the products to which these appearances are owing are highly carbonized. On the contrary, the less a plant is exposed to sunlight, the paler are its colours, the laxer its tissue, the fainter its smell, and the less its flavour. Hence it is that the most odoriferous herbs are found in greatest perfection in places or countries in which the sunlight is the strongest—as sweet herbs in Barbary and Palestine, Tobacco in Persia, and Hemp in the bright plains of extratropical Asia. The Peach, the Vine, and the Melon, also, no where acquire such a flavour as under the brilliant sun of Cashmere, Persia, Italy, and Spain.

This is not, however, a mere question of luxury, as odour or flavour may

be considered. The fixing of carbon by the action of light contributes in an eminent degree to the quality of timber—a point of no small importance to all countries. It is in a great degree to the carbon incorporated with the tissue, either in its own proper form, or as resinous or astringent matter, that the different quality in the timber of the same species of tree is principally owing. Isolated Oak trees, fully exposed to the influence of light, become a tougher and a more durable timber than the same species growing in dense forests ; in the former case its tissue is solidified by the greater quantity of carbon fixed in the system during its growth. Thus we have every reason to believe that the brittle Wainscot Oak of the Black Forest is produced by the very same species as produces the tough and solid naval timber of Great Britain. Starch, again, in which carbon forms so large a proportion, and which, in the Potato, the Cassava, Corn, and other plants, ministers so largely to the nutriment of man, depends for its abundance essentially upon the presence of light. For this reason, Potatoes grown in darkness are, as we say, watery, in consequence of no starch being developed in them, and the quantity of nutrition or amylaceous matter they contain is in direct proportion to the quantity of light to which they are exposed. For this reason, when orchard-ground is under-cropped with potatoes, the quality of their tubers is never good; because the quantity of light intercepted by the leaves and branches of the orchard-trees prevents the formation of carbon by the action of the sun's rays upon the carbonic acid of the Potato-plant. Mr. Knight has turned his knowledge of this unquestionable fact to great account in his application of the principles of vegetable physiology to horticultural purposes.

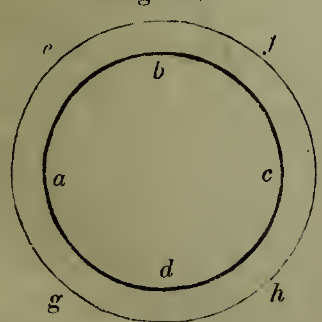
It is to the power which the sun's rays possess of decomposing carbonic acid, and fixing the residual carbon, that many of the directions which the parts of plants assume are ascribable. When, for instance, a branch first quits a stem, its own weight would give it a tendency downwards, if it were not for the effect of light from above, which solidifies the parts exposed to it. Let any one expose a green branch in such a manner that light strikes it only on one side; the tissue of that side will fix most carbon, will become harder, and will lengthen less ; while the opposite will fix less carbon, be less hard, and will lengthen more; the consequence of which will be, that the illuminated side will contract, and pull the branch towards the light. This, if rightly considered, will of itself explain the uniform tendency of the green parts of plants to turn towards the light; and if it will not account for such phenomena as that of the Sunflower turning its flowers constantly to the sun, and following him in his course, as we find repeated by author after author, that circumstance is ascribable not to any defect in the explanations that have just been given, but *to the alleged phenomenon having no existence in nature.*

What, then, with the evaporation of the watery parts, the fixing of a part of the water, and the decomposition of carbonic acid, the crude sap of plants is changed from its original nature to the secretions which are peculiar to different species; but by what other means, unless by the specific action of the vital principle, are established the new proportions of oxygen, hydrogen, and carbon, and occasionally of nitrogen, which are necessary to form the acids, resins, gums, sugars, amylaceous alkaline, and other forms of matter which are met with in plants, is still unknown.

The deposit of these substances, and of the earthy, metallic and other extraneous materials which pass into the system of a plant, along with its fluid nutriment, gradually consolidates the tissue, cases over its sides, chokes up its intercellular passages, and prevents the organic membrane from performing its functions. When this happens, the part in which it occurs dies, or at least ceases to be capable of further action; and thus wood and bark become incapable of conveying fluid, and leaves fall from the branch that bears them. This, which is called the fall of the leaf, has always been a puzzling circumstance to account for. One man has assigned it to the rupture of the spiral vessels which connect the leaf with the stem; another has called it analogous to the sloughing of parts in animals, without pretending to explain the organic cause; others have simply said that leaves fall off because they are dead. Perhaps the following explanation may not be far removed from the truth. The space where the

base of a leaf is connected with a stem may be represented by the circle *a*, *b*, *c*, *d*, *fig*. 93. When both the leaf and stem are in a state of health, they continue to grow equally, the base of the leaf stretching and increasing in diameter as the circumference of the stem is enlarged in consequence of its distention by the wood which is forming within it; and it is obvious, that so long as this mutual adaptation goes on, the organic connexion between the leaf and stem will not be interrupted. But let the base of the leaf, *a*, *b*, *c*, *d*, lose its power of growth, in consequence of being killed by the deposit of foreign substances in it, the growth of that part of the stem which answers to this circle will not therefore be interrupted, but will go on growing, and in time will occupy the space described by the circle *e*, *f*, *g*, *h*. To effect this, all the parts inclosed within the circle *e*, *f*, *g*, *h* must become disjoined from those of the leaf comprehended within the circle *a*, *b*, *c*, *d*, and the inevitable consequence will be the separation of the two, when the leaf will drop off. What gives this explanation the greater appearance of probability is the well-known fact, that leaves do not drop off the stems of Endogens, which never increase in diameter; in such cases they simply perish and rot away. It must, however, be remembered, that whatever value there may be in this explanation of the fall of the leaf, it will by no means account for other instances of disarticulation between different organs, or different parts of the same organ; such as the separation of the upper half of the capsule of the Pimpernel (*fig*. 65 *b*) from the lower, the dropping in pieces of a

Fig. 93.



lomentaceous legume, the separation of the valves of a Cruciferous pod from their frame (*fig*. 68 *c*), and the like. The causes of these things are totally unknown.

Chapter V.

Of Respiration, and of the Effects of Vegetation upon the Atmosphere.

Under the name of respiration we shall include all that is connected with the inhaling and giving off of gaseous matter by plants.

This function is chiefly connected with the absorption of oxygen and carbonic acid, and their expiration. By a vast number of experiments, chemists have determined that the green parts of plants placed in the sun absorb carbonic acid from the atmosphere, and decompose it, giving back the oxygen; and that, at night, they absorb oxygen from the atmosphere, giving off carbonic acid; it is also probable that they part with a small quantity of carbonic acid during the day.

When the first observers remarked that, if green leaves were placed in water in the sunshine, bubbles of air were produced, it was not clear whether the gas originated from the leaves or the water; nor was it known that the bubbles might not be produced by air adhering to the leaves. None have conducted their researches into this curious subject with more care than Theodore de Saussure, Senebier, and De Candolle; the result of whose investigations is briefly this. Three conditions are necessary, in order to secure the disengagement of oxygen by leaves: firstly, the parts must be green; secondly, they must be exposed to the direct action of the solar rays; and, thirdly, there must be carbonic acid in the water.

The circumstance that green parts alone, with a few exceptions, are capable of giving off oxygen, sufficiently proves that it cannot result from what atmospheric air may adhere to the leaves under experiment; and Senebier ascertained that, if the green parts are exhausted of their air by the air-pump, they will nevertheless emit air-bubbles as usual when placed in water in the sunshine. That this is, in fact, a vital action, is proved by dead leaves, still green, having no power of emitting gaseous matter until they begin to decompose.

It is not sufficient to place leaves in bright light to procure the emission of

oxygen by their leaves in water; it must be under the direct rays of the sun. De Candolle found the purest daylight, the brightest lamplight, insufficient to produce the phenomenon: a very curious result, when we consider how large a part of vegetation is seldom exposed directly to the solar rays. Of course nothing like emission of oxygen would occur at night.

It is not even any kind of water in which oxygen will be evolved in the sunshine; neither boiled water, nor distilled water, nor that in which nitrogen, hydrogen, or even oxygen have been dissolved, will produce the result. But if a small quantity of carbonic acid is dissolved in the water, the green parts, stimulated by the sun, disengage oxygen. Various ingenious means have been contrived to prove this fact, and to show that the quantity of oxygen given out is proportioned to the quantity of carbonic acid decomposed; one of the prettiest experiments is the following, by De Candolle: He placed in the same cistern two inverted glasses, of which one (A), as well as the cistern itself, was filled with distilled water, and had a plant of Water-mint floating in it; the other glass (B) was filled with carbonic acid. The water of the cistern was protected from the action of the atmosphere by a deep layer of oil. The apparatus was exposed to the sun. The carbonic acid in the glass B diminished daily, as was obvious from the water rising in it; and at the same time there rose to the top of the glass A a quantity of oxygen, sensibly equal to the quantity of carbonic acid absorbed. During the twelve days that the experiment was continued, the Mint plant remained in good health; while, on the contrary, a similar plant, placed under a glass, filled with distilled water only, had disengaged no oxygen, and exhibited manifest signs of decomposition. The same experiment having been tried, only employing oxygen in the place of carbonic acid, no gas was disengaged in the glass that contained the Mint plant.

This is sufficient to show that the green parts of plants exposed to the sun decompose carbonic acid. By others, not less ingenious, it has been ascertained that the carbon which is the result becomes fixed in the plant itself. It has been found that Periwinkles growing where carbonic acid had access to them, gained carbon; while similar plants, in a situation cut off from the access of carbonic acid, not only gained no carbon, but lost a part of what they previously possessed.

If the green parts are placed in the dark, in a receiver full of atmospheric air, we find that the quantity of oxygen is perceptibly diminished. From this, and many other considerations, we are forced to conclude that oxygen is absorbed by plants at night. This gas does not, however, remain in the system of a plant in an elastic state, for neither the air-pump nor heat will disengage it; but it appears to incorporate itself with the tissue, since solar light readily disengages it. The inference therefore is, that it is absorbed at night, and combines with the carbon already existing, forming carbonic acid, and that the latter is decomposed by the sun, as has before been shown.

Other experiments show, that although the absorption of oxygen and the decomposition of carbonic acid are the principal phenomena of respiration, yet that a small quantity of carbonic acid is given off by the leaves both day and night. Hence Professor Burnet has suggested that, under the name of respiration, two distinct functions are confounded, and that respiration, properly so called, which consists in the extrication of carbonic acid, is incessantly in action; while digestion, which is indicated by the decomposition of carbonic acid and extrication of oxygen, takes place exclusively in daylight.

That the direct beams of the sun are not indispensable to it under ordinary circumstances is proved by the power of plants to form green matter, which is fixed carbon, without being exposed to the sun, as we daily see in individuals growing in the shade; so that it would appear that, in our experiments, plants are not precisely in a condition equivalent to what is natural to them. The paleness, the want of strength, the scentless, tasteless character of such plants may, however, serve to convince us that they have far less power of decomposing carbonic acid than if they grew in the sunshine.

From whence, it may be inquired, is the large quantity of carbonic acid obtained which is thus necessary to the support of plants? Certainly not from the atmosphere alone, for it does not

usually contain more than one part in two thousand of carbonic acid. There can be no doubt that this gas is supplied principally by the earth, in which it exists in great quantity; that a part is obtained from the atmosphere; and that a certain other portion results from the combination of the oxygen of the atmosphere with the carbon of vegetation; and it would seem as if a repeated decomposition and recomposition of carbonic acid was the principal phenomenon in respiration. When we consider how essential it is for roots to be near the surface of the soil, that is, within reach of atmospheric air, and that in all plants the principal part of the roots has a horizontal direction below the surface, we shall see at once the probability that this tendency, when we connect it with the preceding facts, is given them, in order that they may be favourably situated for the access of the carbonic acid, either formed in the soil by fermentation, or produced by the combination of the oxygen of the atmosphere with the carbon of the soil. Theodore de Saussure's experiments completely prove this.

Hence it appears, that while animals vitiate the atmosphere by respiring carbonic acid, plants purify it by absorbing it. It may be said, indeed, that they also deteriorate it by abstracting its oxygen: but it is to be remembered, that if they inhale it at night, they return it in the day-time; and Dr. Daubeny has ascertained that the slight diminution of oxygen, and increase of carbonic acid, which takes place during the night, bears no considerable proportion to the degree in which the contrary effect is observable during the day. Thus Providence provides a living check upon miasmata, and has admirably arranged that one of the kingdoms of nature should render and maintain the world in a state habitable by the other.

It has, indeed, been supposed by some French botanists, that in the beginning, the world had an atmosphere so highly charged with carbonic acid, as to be unfit for the respiration of any animals of a higher order than molluscs; that plants gradually purified it, depositing in the earth the carbon thus abstracted in the form of coal, till the air became fit to be breathed by reptiles, then by mammals, &c., and last of all by man. But although it is certain that carbonic acid is in so great a degree the nutriment of plants, and although Theodore de Saussure ascertained that, in the sunshine, plants thrive in an atmosphere containing twelve per cent. of carbonic acid, yet the same observer found that, in the shade, the smallest dose added to what is ordinarily present in the atmosphere was deleterious.

As plants part with carbonic acid and inhale oxygen at night, some persons have fancied that they must render the air of a room unwholesome; but if we remember that a single human being will vitiate the atmosphere infinitely more than a hundred plants, we shall not attach much importance to this opinion. If it is vitiated at all by flowers, it is by their powerful odours, which in many cases act upon the nerves, and so prove inconvenient to delicate persons.

What we now have seen of the action of the leaves and green parts of plants, will enable us to appreciate the adaptation of their internal structure to perform their functions. We have found them to consist of a number of little cells or bladders, so loosely cohering, that the air has room for free circulation between them; and that by the way in which they are arranged, they present the greatest possible surface to the action of the atmosphere. Although they are inclosed in a thick cuticle, yet they are provided with openings through it, called stomates, by means of which free admission for air is secured, and through which it may be expelled again with facility; when they are submersed, and are, consequently, neither exposed to irregularities of temperature nor of dryness in the air, they have no occasion for either cuticle or stomates, for the water in which they float carries the air dissolved in it to every part; and, consequently, submersed plants have neither. It is true that M. De Candolle entertains doubts whether the stomates are not rather organs of evaporation; but when we consider the relation they bear to the air-cavities in leaves, we can scarcely doubt that they are really respiratory organs; nor does it appear clear why they should not, in fact, perform the functions both of perspiration and respiration. If we hold a leaf of Laurustinus over a candle, so as to heat the air contained in it, without burning the

leaf itself, the air will be expelled through the stomates with such force as to extinguish the flame.

With regard to parts not green, which botanists usually call *coloured*, their function seems to be to absorb oxygen without fixing it, and they appear to possess no power of decomposing carbonic acid when they have formed it. Such is said to be the case with roots, old trunks, petals, stamens, ripe fruits, Mushrooms, and certain Lichens. A part of their carbonic acid escapes into the air, a part is dissolved in their fluids, especially in the roots, whence it passes upwards into the system. Flowers are said to replace a small part of the oxygen they abstract by an exhalation of nitrogen.

Chapter VI.

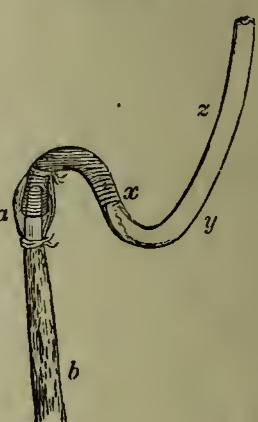
Of Circulation; or the Movements of Fluids in Plants.

Compared with that of animals, there is no such thing as a circulation in the fluid matter of vegetation; that is to say, a movement throughout the system from and to one common point has no existence. This would be impossible from the absence of any common seat of life, and from the exceedingly compound nature of a plant, which does not consist of a single system of growth, but, like a Polype, must be considered as composed of myriads; for each bud has a system of circulation, growth, respiration, and digestion of its own, and a plant is nothing but a great number of such systems combined under one common cuticle, and living in concert.

But although we cannot compare the movement of vegetable fluids to the circulation of the blood, yet it is undoubted that a constant, and sometimes a very powerful, motion takes place, by virtue of which the sap absorbed by the roots rises up the stem, passes into the leaves, flows back in an altered state into the bark, and thence descends towards the roots. Otherwise there would be no means by which the roots could support the leaves at such considerable distances as the spongelets and the tiny foliage are sometimes separated. In the Pines of North West America, for instance, leaves are supplied with food by spongelets which, by calculation, must be four hundred feet distant; and as such leaves are often not more than half an inch long, the force of motion in the sap must be very great, which will enable the leaves to derive support from a distance nearly ten thousand times greater than their own length. In fact, if we wound a tree during the leafing season, the rapid manner in which the sap will flow from the lower lip of the wound brings the phenomenon distinctly before our eyes.

The force with which the sap rises has been the subject of some curious experiments, one of the most instructive of which is the following of Hales, which we give in his own words:— "April the 6th, at 9 A.M., rain the evening before, I cut off a Vine on a southern aspect at *a* (*fig.* 94), 2 feet 9 inches from the ground; the remaining stem *a b* had no lateral branches, it was ⅞ inch diameter; I fixed on it the mercurial gage *a y*. At 11 A.M. the mercury was risen to *z*, 15 inches higher than in the leg *x*, being pushed down at *x* by the force of the sap which came out of the stem at *a*.

Fig. 94.



"At 4 P.M. it was sunk an inch in leg *z y*. April 7th, at 8 A.M., was risen very little, a fog; at 11 A.M. 'tis 17 inches high, and the fog gone. April 10th, at 7 A.M., mercury 18 inches high; I then added more mercury, so as to make the surface *z* 23 inches higher than *x*; the sap retreated very little into the stem, upon this additional weight, which shows with what an absolute force it advances; at noon it was sunk one inch. April 11th, at 7 A.M., 24+½ inches high, sunshine; at 7 P.M. 18 inches high. April 14th, at 7 A.M., 20+½ inches high; at 9 A.M.

22+½, fine warm sunshine; here we see that the warm morning sun gives a fresh vigour to the sap. At 11 A.M. the same day, 16+½, the great perspiration of the stem makes it sink. April 16th, at 6 A.M., 19+⅓, rain; at 4 P.M. 13 inches. April 17th, at 11 A.M., 24+¼ inch high, rain and warm; at 7 P.M. 29+½, fine, warm, rainy weather, which made the sap rise all day, there being little perspiration by reason of the rain. April 18th, at 7 A.M., 32+½ inches high, and would have risen higher if there had been more mercury in the guage; it being all forced into the leg *y z*. From this time to May 5th, the force gradually decreased. The greatest height of the mercury being 32+½ inches; the force of the sap was then equal to 36 feet 5+⅓ inches height of water. Here the force of the rising sap in the morning is plainly owing to the energy of the root and stem. In another like mercurial guage (fixed near the bottom of a Vine which ran 20 feet high), the mercury was raised by the force of the sap 38 inches, equal to 43 feet + 3 inches +⅓ height of water, which force is near five times greater than the force of the blood in the great crural artery of a horse; seven times greater than the force of the blood in the like artery of a dog; and eight times greater than the blood's force in the same artery of a fallow doe."—*Vegetable Statics*, p. 105.

Through what routes the sap passes is a more easy question to resolve. If we cut a stem through about the leafing season, we shall find the albumen, or sap-wood, discharging a great quantity of fluid; the heart wood less; and the bark none at all. If we simply make an incision into a tree, the sap-wood will give out sap in abundance from the lower lip of the wood; the bark none whatever. But if we examine the same parts in the same way at a later period of the year, the upper lip of the wounded bark will discharge a quantity of fluid, but the lower none. Vary these experiments as we please, and the result is always the same. Hence we are forced to conclude, that in Exogens the sap rises through the sap-wood, and descends through the bark; not, however, through the sap-wood exclusively, but through all the parts of the wood which are not absolutely choked up with deposited matter. Of its course, in Endogens and Acrogens, we know nothing worth stating.

But if we cut through the wood of a growing tree obliquely, so as to form a tangental line within its circumference, we shall remark a quantity of fluid oozing from the face of the wound, especially on the face next the bark; and if the tree is preserved in health, the matter from the latter part will continue to ooze out during the remainder of the season, forming a crust of elaborated matter. Hence we must conclude, that, independently of the ascent through the sap-wood, and the descent through the bark, there must be also a lateral transmission from the bark inwards.

What has just been stated belongs to the unquestionable facts in Vegetable Physiology; through what particular forms of tissue sap moves is far less certain. It is not to be doubted that the sap ascends by the woody tissue, as is proved by coloured infusions which are forced to ascend by artificial means; but whether through the tubes of woody fibre, or by the intercellular passages, has not been, and probably cannot be, decided. It is also a question whether it ascends or not by the dotted ducts and the vessels; there can be no doubt that these parts, with the exception of the spiral vessel, appear to be filled with fluid when the sap is in its most rapid course; but it is equally certain that the dotted ducts, at least, are empty afterwards: are we to conclude that these forms of tissue perform one function in the spring, and another in the autumn; or are we rather to suppose that the appearance of being filled with fluid, which they exhibit in the spring, is owing to the wounded vessels in their neighbourhood overflowing into them when cut through? There is no satisfactory answer to this as yet upon record. In its downward descent it may be reasonably assumed that both the fibrous and cellular parts of the tissue assist in its conveyance; but it is to be suspected, that although we speak of them in this general manner, yet that in reality these two forms of tissue do convey different kinds of fluid; because we find certain secretions most abundant in the bark, such as gum, and others, such as astringent matter, equally abundant in both the wood and the bark. Perhaps the woody fibre, which is not directly connected with the medul-

lary processes, brings downwards gummy and similar matters, while others pass freely down the cellular tissue. The medullary processes undoubtedly carry on the horizontal transmission, and are the means by which the circumference communicates with the centre of a tree. This their position, the direction of their tissue, and their appearance during the growing season, render sufficiently manifest.

From the latest experiments, and the best conducted arguments, it would seem that the cause of the movement of the sap upwards is, as far as we have any means of assigning an immediate cause to the phenomenon, the development of the buds and leaves. When a young bud, or a leaf, is first excited to growth in the spring, the fluids it contains are increased in density by evaporation; endosmose immediately takes place between it and the tissue below it, which latter parts with the thinnest portion of its contents, and then acts by endosmose upon the tissue below it, and thus the whole chord of vegetation is set in vibration, if we may so express it, from the extremity of the branches to the points of the root; the moment the spongelets are affected, the fluid in the soil is attracted through their sides, and thus a complete motion throughout the system is established. Hence the leafing of trees is not the effect of the ascent of the sap, as it is usually thought to be, but the cause of it. It may be supposed that the mere effect of gravitation will carry downwards the sap in its densest state after it has ceased to obey the attraction of the leaves, and that it will descend by simple filtration till it reaches the roots; but how we are to account for its lateral transmission through the medullary rays is still unknown.

The sap of plants then ascends in its crude state through the sap-wood, and reaches the leaves; is there finally decomposed, assimilated, and inspissated; is discharged back into the bark; settles downwards towards the roots; and passes off laterally by the medullary passages into the heart-wood. Heart-wood is, in truth, nothing but sap-wood consolidated by the addition of secreted matter, and may always be restored to the state of sap-wood by any solvent of the secreted matter. Ebony, for example, is jet-black; when young it is whitish, and it only gains colour as the black substance is generated in the leaves discharged into the bark, impelled into the medullary processes, and by them deposited in the wood. Plunge a piece of ebony into hot nitric acid for a few minutes, the colouring matter will be discharged, and the tissue will be restored to the state of sap-wood.

Besides this kind of general motion, which seems indispensable to the very existence of a plant, and which our reason would have told us must exist, if our experiments failed in revealing it to our sight, there is another which no force of reasoning could have led us to expect, and which is altogether of a local and partial character. It was originally ascertained by Amici, that in the Chara plant there is a curious rotatory motion in the fluid of each cell of which that plant consists. It may be described as a revolving movement round the inside of each cell, ascending on one side and descending on the other, with an occasional irregular interchange of matter between the sides; and, what is very curious, the ascending current is uniformly on that side of each cell which is most remote from the axis of growth, and consequently the descending current is on the side nearest the axis. Some excellent observations upon this phenomenon, by Messrs. Solly, Slack and Varley, will be found in the *Transactions of the Society of Arts*, vol. xlix. to which we would especially direct the attention of the reader. After finding it in Chara, and its kindred genus Nitella, it was discovered in the cells of the Frogbit (Hydrocharis Morsus Ranæ), a common water-plant, and in the hairs of so many species, that we are led to suspect it to be a phenomenon by no means confined to the cases in which it has been observed, but of universal occurrence; and that it may be connected with the assimilations of fluid and gaseous matter by the tissue: it may, in fact, be a movement of digestion, going on by night as well as by day. A vial-microscope, for the express purpose of showing these motions, has been ingeniously contrived by Mr. Varley, and may be procured from the optical-instrument makers. It is fully described in the 50th volume of the *Transactions of the Society of Arts.*

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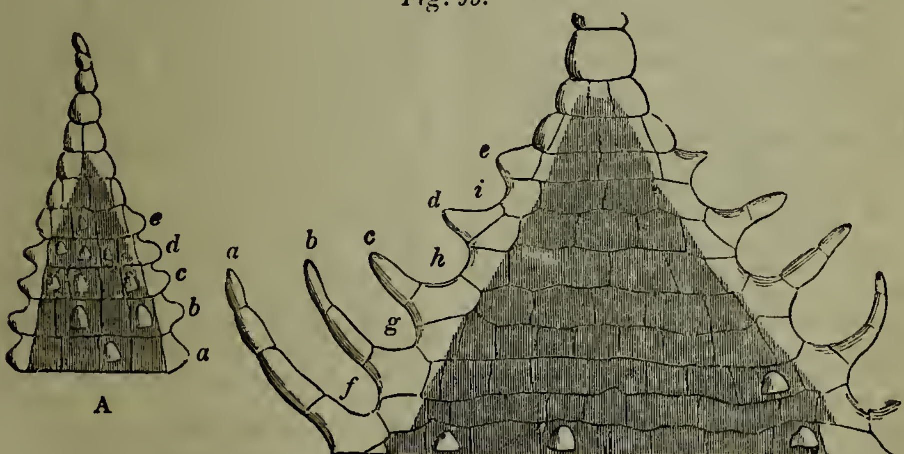
Chapter VII.

Of the Growth of Plants.

Concerning the precise manner in which new cells or tubes of tissue are generated, little very satisfactory is known. By some it has been fancied that they were produced by the extrication of gaseous matter in solidifiable mucus; others have hardily asserted that the minute green globules, which we find sticking to the sides of tissue, are young cells or tubes, and that they grow from their mother-cells as seeds grow from their placenta; suffice it to say that these are mere *assertions*. All that we really know about the matter is this: that in Chara and Nitella, young cells appear like buds at the point, or axils of older cells, and gradually lengthen out into the tubular form peculiar to those plants; and that in Marchantia polymorpha they have been seen, by Mirbel, to form in a somewhat similar manner. He states that a lobe of that plant, such as is represented at *fig*. 95, A, changed to such a lobe as is shown at B, which he explains in the following manner. The young lobe, A, presents on its surface, at its widest part, five rows, *a, b, c, d, e,* of cells, arranged parallel to its basis. The two cells which terminate each row, one to the right, the other to the left, are inflated and conical, and, consequently, form two marginal projections. The five rows, *a, b, c, d, e,* are united without intermediate tissue. The older lobe, *fig*. 95, B, shows nine rows, *a, f, b, g, c, h, d, i, e,* of cells, placed parallel with its base. Five of these rows, *a, b, c, d, e,* terminate, right and left, by a marginal cone, formed of a single cell, or, which is more usual, of two, three, or four cells attached end to end. The four other rows of cells, *f, g, h, i,* are placed between the first, so as to alternate with them, and they have no marginal appendages. It is evident, notwithstanding the augmentation of the number of the cells, that the five rows, *a, b, c, d, e,* of *fig*. 95, B, and their conical appendages, represent the five rows of cells, *a, b, c, d, e,* of *fig*. 95, A, with their marginal projections. But the four alternate rows, *f, g, h, i,* of *fig*. 95, B, have no representatives in A; and as the latter is the younger of the two, we must conclude that the four alternate rows of the other lobe were developed subsequently to the formation of the five rows with appendages.

Fig. 95.



We have quoted this at full length because it appears to be the most important, the most clearly demonstrated, and, it might be added, the only tangible observation that has yet been made concerning the development of tissue. If it does not explain the increase of solids, such as stems and the like, it seems to be, at least, applicable to leaves and all their organs; the unevenness of whose edges, *in all cases* seems to increase the probability of their really being developed upon this plan.

When a branch or a young plant first begins to lengthen, it is merely a bud, reposing upon a certain quantity of cellular tissue, which in Exogens is pith, and which is always highly charged with fluid. The moment light

and heat are sufficiently powerful to produce a decomposition of carbonic acid and a thickening of the fluids, endosmose is set in action, and produces a current from below upwards, which is variable in intensity in different species, but which always acts as a force fr m behind, impelling the tissue in the direction of its own current. The tissue of the buds, young and soft, and scarcely at all solidified by the deposit of carbonaceous, earthy, or other matters, yields freely to the impulse, stretches, lengthens, and grows, preserving its rectilinear direction, so far as is practicable, considering the action of the light upon it, and the unequal carbonization of its sides. But the instant the leaves begin to develope, they decompose carbonic acid, assimilate the fluids sent into them from the stem, evaporate the superfluous moisture, and returning the inspissated sap downwards, gradually harden the tissue of the circumference. Thus, as De Candolle well remarks, a branch, during its increase in length, is under the influence of two opposing forces; the one, from below, softening its tissue and forcing it to lengthen; the other, from above, solidifying it and rendering it incapable of elongation. This fact, about which there can be no doubt, explains how it is that the branches of plants growing in wet and shady places, are long, succulent, and brittle; while those produced in hot, dry, and sunburnt places, are short, stiff, tough, and stunted. In the first case the force of elongation is not sufficiently overcome by the decomposition of carbonic acid, &c., and the consequent solidification of the tissue; in the latter, the force from below, in itself is feeble, and is very much overcome by the powerful action of the leaves, and the degree in which all the parts become hardened. It is only when neither shade nor sunlight are in excess that the pliable, tough, and evenly-formed branches of trees are produced. When the force from below is entirely overcome by the force from above, branches cease to grow.

In general, plants increase but little in diameter till their full annual length is nearly attained; but as soon as that has happened, they enlarge sensibly, and often rapidly, forming woody matter. In what manner this is brought about has been a fertile subject of controversy, in which physiologists have scarcely been unanimous in anything till lately, when they seem to agree in admitting this, that wood is sent downwards from the leaves. If you tie a ligature round the branch of an Exogen, the diameter above the ligature will increase, that below it will remain without alteration. And if you wound an Exogen by cutting off a large patch of its bark, new woody matter will form upon the upper lip of the wound, and no where else.

Fig. 96.

This point being settled, opinions have been pretty generally divided between two inferences; the one, that wood is organized matter, sent directly downwards from the leaves and buds; the other, that it is produced by the organizable matter formed in the leaves and given off by the bark. There are difficulties in the way of either of these suppositions; but those relating to the first appear all susceptible of satisfactory explanation; while nothing like an answer has been made to the objections to the latter.

If you take the branch of a Lilac when it is just clothed with leaves, and while the bark will freely separate from the wood, and peel it, you will find ridges of tubes passing downwards from each leaf, turning aside (*fig.* 97) at every

Fig. 97.

little obstruction, re-uniting after the obstacle is passed, and, together, forming a firm fibrous case to the subjacent

wood of the previous year. In others, the fibres may be traced in like manner from the leaves; but instead of running parallel with each other, they cross each other diagonally, and form a sort of lozenge work. This is wholly inexplicable upon the supposition that wood is deposited by the bark; but it is clearly intelligible if the wood is regarded as an organic emanation from the bases of the leaves. Again, in Endogens, the woody fibres may be distinctly traced into the leaves, from which it is plain that they originate; and in this case, at least, it is manifest that the woody bundles cannot be organized matter deposited by the bark; for they are in the centre, while the bark is at the circumference. We therefore cannot resist the conclusion that wood is organic matter emitted from the bases of the leaves, passing partially down the bark, and rendering the liber fibrous, but principally confined to the wood.

Du Petit Thouars, indeed, went so far as to assert that wood is, in fact, composed of the roots of buds and leaves, inclosed below a common bark, and that plants are, in fact, communities of individuals, each having an independent existence, although combined in one common system. When we consider that buds have the power of emitting roots when cut off the plant on which they grew; that in the Dragon tree if one bud vegetates, upon a trunk otherwise dead, as sometimes happens, the bud, having no longer a series of vital systems with which it may combine, sends out undoubted roots beneath the bark, instead of the woody fibres that it would have emitted under ordinary circumstances; and that, in other cases, when wood has died, the living buds have formed a sort of entangled sheath of roots by the fibrous matter they have sent downwards; when we seriously consider these things, it is impossible not to admire the genius which led Du Petit Thouars to advance so bold a doctrine, and difficult not to assent to its truth.

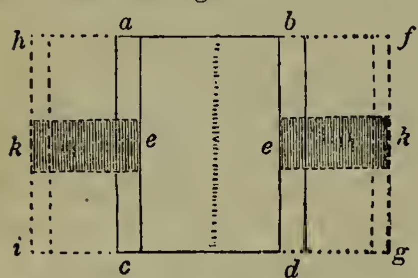
Without, however, embarrassing ourselves with this speculation, which is not of much practical importance, it may be safely asserted that there is no possibility of accounting for all the phenomena connected with the formation of wood, without understanding it to be produced by organic matter proceeding directly from the buds and leaves.

We must, then, adopt the following theory of vegetable growth, which, we believe, will be found conformable to admitted facts, in all the divisions of the vegetable kingdom. A plant is a mass of cellular tissue, capable of expansion and growth in all directions. When there is no leafy system, growth is indefinite, and not carried on in any particular direction, and no woody system is formed; but when leaves are developed, they send their organic fibres down through the mass of cellular substance, and arrange them sometimes in one way, sometimes in another, according to the specific powers of a plant. Upon this supposition the stem of a woody plant will be composed of two essentially distinct systems; the one cellular, constituting the pith, the principal part of the bark, and the medullary processes (if an Exogen), and capable of growth in all directions; the other fibro-vascular, comprising the wood and a part of the bark, and capable of growth longitudinally only. It will be found that this will answer all the objections which have been made to wood being an organic emanation of the leaves.

The following is a favourite argument with those who believe wood to be a superficial deposit from the bark. If, say they, a ring of bark is removed from a maple-tree, whose wood is white, and its place is carefully supplied by a ring of bark from a maple whose wood is red, the new bark will adhere to the old wood, uniting organically with it, so that, externally, the wound will be scarcely seen. Let a tree thus treated be allowed to grow for a year or two, and a quantity of wood, generated in the leaves, will be found beneath the ring of the red-wood maple; and being the produce of leaves and buds furnishing white wood, it should be white also, if, indeed, those organs really have the power of generating wood as is supposed. But it will be found that red wood will have been formed below the red bark; therefore wood is a deposit from the bark. This is one of those forms of fallacious reasoning which are the best calculated to catch the unwary, but which will not bear examination. The facts stated in it are true, but the inference is false, as will be intelligible from the following

diagram:—Let the letters *a*, *b*, *c*, *d* (*fig.* 98) represent a section of a tree, round whose wood (*a c* and *b d*) a ring of red bark (*e e*) has been made to grow. As soon as the diameter of such a piece of wood commences to increase, it is by a double action; the first arising from the *horizontal* expansion of the cellular system of the bark and medullary processes, which will remove the bark, *a*, *b*, *c*, *d* to *f*, *g*, *h*, *i*; and consequently the red ring *e* will advance to *k*; the second depends upon the introduction of the fibro-vascular system of the wood *longitudinally* among the horizontal system, to make room for the former of which, the latter is constantly growing. Now the colour of young wood depends entirely, and of old wood in a great degree, upon the colour of the medullary processes or horizontal cellular system; and consequently as the ring of red bark, which is a part of the same system, has grown outwards (that is from *e* to *k*) as the tree has increased in diameter, it would necessarily form a zone of red matter below it; and this would not be in the least interfered with in appearance by the new wood descending from above, because the latter, being colourless, would derive its colour from the horizontal system of the medullary rays, through which it would pass in its descent.

Fig. 98.



In like manner all other objections, however plausible, which have as yet been made to this view of the origin of wood, are to be answered with equal facility.

It is not, perhaps, of any practical importance to ascertain which theory of the origin of wood is the most correct, now that physiologists are, at all events, agreed upon its being produced in some way by the action of leaves freely exposed to sun or bright light. And this is abundantly sufficient to show the cultivators of trees the great importance of thinning their plantations carefully, without having recourse to severe pruning, which necessarily diminishes the power of the plant to form wood, because it deprives it of the leaves by which exclusively wood is generated.

Chapter VIII.

Of the Relation of Vegetation to Seasons.

Repose from growth seems periodically necessary to most plants, and accordingly we find there is no country without a season of growth and a season of rest—whether they are called by the name of winter and summer, or rainy season and dry season. This fact is connected with several considerations to which we have not yet adverted. What is about to be said has reference to the seasons of the North of Europe it is left to the reader to apply the ob servations to the climate of other parts of the world.

In the winter, we commonly say that all vegetation is at rest, that the sap ceases to flow, new parts to be developed, and old parts to enlarge. But this is not exactly true. It appears, from experiment, that vegetation is at all times more or less active; and that we ought to say, that it is languid in winter, and energetic in the spring and summer. The fact of many plants retaining their leaves, of others swelling their buds, and of all forming an addition more o less considerable to the points of their roots during winter, sufficiently attest the movement of the fluids, and the existence of vegetation even at that season. This is further proved by the well-known fact, that trees planted in the autumn become turgid with the fluid absorbed by their roots during winter; and as it appears from the French newspapers, by some recent experiments of M. Biot, who is represented to have succeeded in obtaining a flow of the sap from certain trees in mid-winter.

But whatever power of attracting sap by its roots a plant may possess during winter, it is obvious that it has little means of parting with any part of it again by evaporation at that period of the year; so that during the winter the whole of the tissue must gradually acquire a state of turgidity which will go on increasing till the leaves and new branches are developed

and carry off the sap, or decompose and assimilate it.

This turgid state is eminently favourable to rapid growth when vegetation once resumes its activity; for it acts as a force from behind, which continually presses upon the new-born tissue, and causes it to expand. It is well known that after very long winters, or when a plant has been prevented by artificial means from shooting at its usual season, its branches and leaves are developed with extraordinary vigour; a circumstance which has been ascribed to *accumulated irritability*, but which is in fact owing to the turgid state of the tissue.

It is when the temperature of the air is raised sufficiently high, that the vital energy of a plant is excited, and buds are developed with their leaves. Light has certainly nothing to do with this phenomenon, although it afterwards colours and consolidates the young parts; for if a plant is exposed to an elevated temperature, in total darkness, its growth takes place as if in the light. The common experiment of introducing into a hothouse the branch of a Vine growing in the open air, is another familiar illustration of this fact: the temperature of the hothouse excites the buds into action, they immediately attract fluid from beneath them, and thus the whole system is put in motion, although the Vine-plant may be exposed beyond the house to all the inclemency of winter. De Candolle has proved by a simple experiment, that in such a case as this the fluid consumed by the young leaves is really attracted from out of the cold earth, and not absorbed from the atmosphere of the hothouse. If you select a tree with two principal branches, and two principal roots to correspond with them, and adapt to each root in the earth a bottle of water, you will find that the bottle that corresponds with the branch in the hothouse will be quickly emptied, while that which is connected with the branch in the open air remains nearly full. It may be supposed that in a natural state of things a corresponding effect is produced upon the roots by the warmth of the surface of the soil, and that they also are stimulated into activity; but it is doubtful whether this amounts to much, if, indeed, it is of any importance whatever: for provided only the earth is not frozen, it appears from experiments that heat applied to the branches alone is quite sufficient to determine and maintain all the phenomena of growth.

Once set in action, the branches of a tree go on growing according to the laws which have now been explained. They and their leaves, by degrees, gain their full growth; bark and wood separate, and cambium deposited between them; the leaves decompose the fluid they receive, send their fibres down within the substance of the branches, gradually secrete the substances peculiar to each particular species, and transfer them to the bark; and finally, becoming clogged at every pore by the earthy and carbonaceous matters that are deposited during the processes of digestion and evaporation, cease to act efficiently as leaves. In this state they are principally protectors of the young buds in their axils. If the latter have been formed very early, they are so far advanced in their growth by the middle of the summer, that they have already arrived at the same state as later-formed buds will be in at the commencement of another spring. Acted upon by the temperature of the season, they develop and call into play the same class of phenomena as took place in the beginning of the spring: the sap, which had become languid as the leaves became impotent, is again stimulated to a rapid movement, and is secreted anew in increased quantity. This is indicated by what gardeners call the running of the bark; that is to say, the bark and wood of Exogens separate spontaneously as in the spring, depositing a layer of cambium between them. Thus are formed what are called Midsummer-shoots, which only occur in plants which bud very early in the spring.

In the course of the autumn, the increased and prolonged heat and drought complete the destruction of the leaves, which had already begun to languish: all their vital actions are destroyed by the quantity of foreign matter with which their cells, their stomates, their vessels, and their intercellular passages are filled, and they drop off.

At this time a plant is nearly exhausted of its fluid sap, the watery portion of which had exhaled during the summer and autumn: all the parts are dry and solidified, so as to suffer little from evaporation; and the roots themselves, having for some time

been but feebly in action, are firm and not liable to be easily broken; everything is in a state of languor, and prepared to renovate the enfeebled powers of the plant by the slow and gradual absorption of fluid during the winter.

It is in the autumn, then, that both theory and practice direct us to transplant trees. At that season every circumstance concurs to render the operation practicable; but if we wait till the spring, the spongelets which form during winter are likely to be destroyed, and many causes may call the already turgid plant into growth, before the roots have had time to form new spongelets.

The seasons of growth and repose are so essential to vegetation, that, as is familiar to all gardeners, it is scarcely possible to prevent plants preparing themselves for their annual changes, whatever artificial means may be employed to maintain them in a uniform atmosphere, and to protect them from those causes which usually bring about repose; and this is certain, that if we can succeed in preventing the cessation of growth, the plants which are the subject of the experiment uniformly, in the end, fall victims to the forced and unnatural condition in which they are maintained.

If annual changes in their condition are requisite to the well-being of plants, so in like manner are the diurnal changes of light and darkness. If plants were kept incessantly growing in light, they would be perpetually decomposing carbonic acid, and would, in consequence, become so stunted, that there could be no such thing as a tree, as is actually the case in the polar regions. If, on the contrary, they grow in constant darkness, their tissue becomes excessively lengthened and weak, no decomposition of carbonic acid takes place, none of the parts acquire solidity and vigour, and finally they perish. But under natural circumstances, plants, which in the day become exhausted by the decomposition of carbonic acid, and by the emptying of their tissue by evaporation, repair their forces at night by inhaling oxygen copiously, and so forming a new supply of carbonic acid, and by absorbing moisture from the earth and air without the loss of any portion of it.

Such being the case, we must conclude that plants grow chiefly by day, and this is conformable to the few observations that have been made upon the subject. Meyer found the stem of a Belladonna Lily, and plants of Wheat and Barley, grow by day nearly twice as fast as at night; and Mulder states that he has arrived at a similar result in watching the development of other plants.

Chapter IX.

Of Vegetable Secretions.

One of the most important consequences of the decomposition and assimilation of their sap by plants is the formation of various secretions which are often peculiar to particular species. The production of these we must of necessity ascribe to the varied powers of the vital principle, for we cannot otherwise conceive in what manner the unelaborated fluids of the earth, or the gases mixed with the atmosphere, are converted to such a prodigious number of different products, by the uniform action of phenomena which are common to all plants.

These secretions are what give hardness and durability to wood, (while their absence renders it perishable,) flavour to fruit, and odour to flowers; which form the bitterness, acidity, or acridity of some, and the mucilaginous, farinaceous, saccharine, and other qualities of other species. Occasionally they may be perceived by the eye, assisted by the microscope, formed in regular crystals, having an acicular or prismatic figure, when they are called *raphides* (*fig.* 91); but most commonly

Fig. 91

they are amorphous and confounded with the tissue, or exist only in a fluid state. The nature and chemical proportions of these substances concern botany but little, and therefore a detailed account of them must be sought in the works of chemists. They are, however, in some things so intimately mixed up with physiological considerations as to require a short notice.

Pure vegetable secretions, of whatever kind, must, as has been already

shown, be the result of the combination of water and carbonic acid; that is, they must consist of the elements of water, with the addition of a variable amount of carbon; to which must be added nitrogen in some cases. And thus of an hundred and sixty-three distinct principles, which chemists have analyzed in the vegetable kingdom, there is not one of which oxygen, hydrogen, and carbon are not the elements; twenty-eight of them only having been found to contain nitrogen. In many cases the proportions in which these elements are combined are so similar in different principles, as in gum, starch, sugar, and lignine, that a very little change in the circumstances under which they are produced will suffice to convert the one into the other, so that they have even been considered as being all varieties of sugar itself. It is probable that all of this class, which De Candolle calls *hydrocarbonates*, are principally destined as nutrients of the young parts, and that they ought to be distinguished in regard to their functions from the acids, resins, alkalies, oils, and other secretions, which have apparently nothing to do with nutrition. They will accordingly be treated of separately in this place.

§ 1.—*Nutritious Secretions.*

Of the hydrocarbonates *gum* is the most common; it is found in the bark and wood of all plants in some proportion, and in many in great abundance. In the Cherry, the Arabian Acacia, the Tragacanth plant, and all those others which are called gum trees, it flows out in plenty when their bark is wounded, or when the surface of it cracks. The mucilage with which the sap is mingled immediately upon its introduction into the roots, and which is perhaps universal throughout the vegetable kingdom, and the jelly of the Grape, the Gooseberry, and other succulent fruits, are mere forms of gum. In short, the substance, being in reality nothing more than condensed water and carbon, is exactly what would be formed in common by all leaves, independently of the special power which different species may possess of secreting peculiar substances in addition.

Fæcula or *Starch*, different as it is vulgarly considered, seems to be really little more than gum divided into minute portions, each of which is inclosed in a cell of tissue; and it is said to be the latter only which is coloured blue by iodine. It is converted into grape-sugar by the addition of acids, and alkalies render it soluble. While gum itself may be considered the nutrient principle of vegetation, lying freely among the system of a plant, and constantly in action, starch is apparently the same substance stored up in such a manner as not to be readily soluble in the water of vegetation; and this, as De Candolle well observes, appears to agree very well with the office that starch has to perform in the vegetable economy, namely, that of forming a reservoir of nutritious matter, which is to be consumed in supporting a plant at particular periods. Thus we find it stored up—1. in the albumen of Corn, of the Buckwheat, and of a multitude of other plants; 2. in fleshy cotyledons, such as those of the Bean and the Pea, which like albumen are magazines of food for the support of the embryo plant; 3. in tubers intended to nourish young shoots, as in the Potato, the Jerusalem Artichoke, the Arrow-root plant, &c.; 4. in all fleshy roots which have to furnish food to the young stems when they first begin to grow, as in Briony, and in the Inula Helenium, which furnishes the starch called inuline; 5. in all bulbs, or root-stocks having a similar destination; 5. in the centre of the stems of endogens, as in the Sago palm, which is a reservoir of food for the leaves when they first begin to grow; 6. in the receptacles of such plants as the Artichoke, where it acts as food for the young flowers; and in the liber of some trees, as the Pine and the Birch, and in the rind of certain fruits, such as the Date, the Bread-fruit, &c.

In all these cases the starch is either capable of supplying food to the young parts of the plant, or may be supposed to be provided for the sustenance of man. That the former is its more immediate destination is probable from its continuing to increase during the latter part of the year when the plant is preparing a fresh supply, reaching its maximum when the plant has ceased to grow, remaining stationary during winter, and rapidly diminishing with the growth of the young shoots in spring. Thus it is stated in a French agricultural work, that 100lbs. of Potatoes contained the following proportions of starch:—

August . . .	10lbs.
September . .	$14\frac{1}{2}$
October . . .	17

March	17lbs.
April	13¾
May	10

In what way starch is adapted to the power which plants possess of absorption is not by any means clear. We know that it is only soluble at a temperature little below that of boiling water, when the organic integument of each little grain bursts, and allows the gummy matter it contains to flow out; but we have no such temperature in nature, not even in germination. De Candolle suggests that the action of several substances which exist along with starch, such as tannin and alkaline matters, may, in particular cases, cause a rupture of the integument, and liberate the gummy matter.

Sugar may be considered as starch, with an addition of oxygen, and consequently we find that the simple absorption of oxygen by seeds, when germinating, is sufficient to change their starch into sugar. Thus Barley is converted into Malt, by being forced to grow in the dark; and we find the fæcula that is present in flowers before they expand, converted into honey by the excessive absorption of oxygen which then takes place (see Chapters X. and XIII.) Like most of the secretions of plants, it is produced in greater quantity in southern than in northern latitudes. The Sugar-cane is scarcely sweet in our stoves, the richest Figs and Grapes that can be produced by artificial means in England will bear no comparison with those of the Mediterranean; and while the Chestnuts of the south of France contain as much as fourteen per cent. of crystallizable sugar, those of the north of Europe are almost sugarless. Is this owing to temperature? We think not; for the mean heat of a forcing-house in England is greater than that of the Levant. It is rather to the subtle and incomprehensible agency of light, which we have no means of imitating, that those important differences are to be ascribed. Sugar, like starch, appears to be intended for the nutrition of young organs; we find it abundantly in the ascending sap, whence it is transferred to the leaves; it is formed out of starch during germination for the support of the embryo plant, and during flowering for the food of the fertilizing organs; and it is carried off from the roots of herbaceous plants by the new leaves when they sprout in the spring. The Beet-root, for instance, rich as it is in sugar at the end of autumn, contains scarcely any after the leaves have been growing a short time in the spring; and the same is the case with Turnips and similar roots.

As gum, starch, and sugar seem to be the great nutrient principles of vegetation, it would be supposed that *lignine*, which is the result of their organization, must be extremely similar to them in composition. And such is really the fact, as will be obvious from a comparison of their chemical analysis as furnished by Gay Lussac and Thenard.

	Carbon.	Oxygen.	Hydroge
Gum	42·23	50·84	6·93
Starch	43·55	49·68	6·77
Sugar (of the cane)	42·27	50·63	6·90
Lignine	52·00	41·25	5·75

Lignine, therefore, differs from gum, starch, and sugar, principally in its elements consisting of a larger proportion of carbon; and it is not improbable that the quality of timber depends, to a considerable extent, upon the amount of its carbon; for although but few researches have yet been made into this curious question, yet as far as they go they seem to indicate such to be the fact. De Candolle gives the following proportions of carbon from the works of Gay Lussac and Thenard, and of Prout:—

Cormonna Wood	55	per cent.
Iron Wood	53·44	
Oak	52·53	
Beech	51·45	
Box	50	
Willow	49·80	

From these and similar considerations of the nature of the nutritious secretions of plants we may draw the following conclusions:—The rising sap passes into the leaves charged with carbonic acid, or matter capable of being converted into it; it loses a large proportion of its water by evaporation, and of its oxygen by the decomposition of its carbonic acid, and thus becomes reduced to carbon and water in an inspissated state, which is gum when free, and lignine when fixed. From the lignine is organized the tissue, among which the gum circulates for its support and consolidation, and within which it is also enclosed, and elaborated into various other principles, remaining as starch when but little changed. A portion of the gum settles

downwards through the stem: that part which is in the bark, being intercepted by no opposing current, finds its way down into the roots; such other part as finds itself in the alburnum is caught by the ascending current of sap, dissolved in it, and carried again into the leaves, there to undergo changes similar to what it had previously experienced. Whenever the gum meets in its course with cells that are empty, it is absorbed by them, and becomes subject to their special vital powers, changing to the principles which each particular species or organ has the property of elaborating, and the most readily to those which, like sugar, have the greatest chemical resemblance to itself.

§ 2.—*Special Secretions.*

Besides the secretions just spoken of, there are many others which are diffused through the system of certain plants, but which neither appear to contribute to the process of nutrition, nor enter into the general plan of vegetation, but are confined to particular species. They may be classed under the heads of milky fluids, resins, volatile oils, and fixed oils.

Milky fluids are generally characteristic of certain natural groups of plants, existing in every species, if in any; as is the case in Euphorbiaceous, Apocyneous, Papaveraceous, and other plants. When such are wounded, the milky fluids are forced out from both lips of the wound, showing that it is discharged in consequence of a contraction of the tubes or cavities in which it lies. These latter are of various kinds: sometimes they are long, thin-sided tubes, resembling the intestine of an animal; and sometimes they are rows of thick-sided cubical cells, such as are represented at *fig.* 90 *c.* By Schultz and Meyen, indeed, they are described as vessels of a particular kind, which the former calls *vital;* but there is every reason to believe that some error of importance is connected with their observations; for no one in this country has yet been able to discover what those gentlemen talk of having seen. Milk is usually white; but it is frequently orange, as in Celandine and the Gamboge tree; and it is occasionally crimson: in common Purslane it is said to be brownish-green. De Candolle distinguishes three sorts of milky fluid:—1. That in which caoutchouc is present. This is most common in plants of hot latitudes, hardly existing in the temperate zone under natural circumstances. It is most abundant in certain Apocyneous plants, such as Urceola elastica and Vahea Madagascariensis, which furnish the India rubber of India; and in some Euphorbiaceous species, such as Hevea Guianensis, or Artocarpeous ones, like Ficus elastica, from which that of other tropical countries is obtained. These are usually acrid and poisonous, although they are occasionally wholesome when the parts are young and have been exposed to heat. 2. Narcotic milk, in which opium is an essential ingredient, such as is met with in Poppies; and 3. A sort, of which fibrine is a principal component. This substance, which is very like animal fibrine, is characteristic of the milk of the Papaw-tree, and of the Cow-tree, whose milk is said, besides fibrine, to contain half its weight of vegetable wax.

When plants whose juice is milky are employed for food, any method which either prevents the formation of the milkiness, or by which it is removed when formed, is found effectual to render them then a safe aliment. Blanching, in particular, is attended to a certainty with the effect of removing noxious qualities, inasmuch as milk, like all other secretions, can only be formed when the leaves are fully exposed to light: the same thing happens when plants are very young, when they have not had time to elaborate their secretions, by attending to which the peasants of Languedoc are said to eat young Wild Poppies with impunity, and further, as it is through the bark that such secretions descend, any part of the wood will be harmless in plants whose milky bark is poisonous. Thus the peasants of Teneriffe are enabled to suck the cooling lymph from the wood of a highly poisonous plant called Euphorbia Canariensis, by first stripping off its bark.

Resins are common in the bark of several natural orders, especially of coniferous plants; they are also met with in the wood, and even in the pith. They have no tissue specially provided for their reception; but form for themselves, by their own proper weight, irregular fistular cavities. It appears as if a small quantity of resin first collects, and having formed a cyst, attracts more of the same substance to itself; and then acquiring volume and weight,

settles down among the cells or tubes, forming what are called turpentine vessels.—(*See* page 71.)

Volatile oils are found nowhere but in the leaves, flowers, or bark of plants, where, like resins, they form little cysts for themselves. Occasionally they are present in the pericarp or the seed, as in Anise and Coriander in the former case, and in the Nutmeg in the latter. They are said to be composed of two distinct principles—*elæadine*, or the volatile, and *stearoptine*, or the concrete portion. These two are usually intimately combined in nature, so that they can only be separated by artificial means; but De Candolle thinks that, in the case of Camphor, we have the stearoptine in a separate state in nature. This substance is of by no means uncommon occurrence. Combined with a volatile oil it exists in Rosemary and Marjoram to the amount of 10 per cent., and in Lavender of 25 per cent; but in a naturally concrete state it occurs only in certain Laurels, such as the Laurus camphora and Sumatrensis; and in a large tree of the Malayan Archipelago, called Dryobalanops camphora, in whose bark, roots, and wood it is secreted in tears varying in size from a pea to that of a grain of sand.

Fixed oils have neither special forms of tissue nor irregular cavities within which they are deposited; but, like starch, they occupy and fill the interior of common cells. It is neither in the leafy nor cortical organs that they occur, but chiefly in the seed, as in the Flax; or occasionally in the pericarp, as in the Olive. They are more especially common in albumen, as in Palma Christi; and may probably be considered as a secretion which concurs, in some unknown manner, to the nutrition of the embryo plant. As there is scarcely any vegetable product more extensively useful than fixed oil, nor one which is more generally sought for mercantile purposes, it will not be without interest to know in what proportions it has been found to exist in the various seeds from which it has been pressed for profit. For this reason we borrow the following table from De Candolle:—

Seeds of the	Per cent. in weight.
Hazel Nut	60
Garden Cress	56 to 58
Olive	50
Walnut	50
Poppy	47 to 50
Almond	46
Common Spurge (Euphorbia lathyris)	41
Colza Rape	39
White Mustard	36
Tobacco	32 to 36
Plum	33
Common Rape	33
Summer Rape	30
Woad	30
Gold of Pleasure	28
Hemp	25
Fir	24
Flax	22
Black Mustard	18
Sunflower	15
Buck-wheat	12 to 16
Grape	10 to 18

§ 3.—*Local Secretions.*

Besides the two foregoing classes of secretions, there is a very considerable number which never enter into the general system of vegetation, and which have no particular situation, being found indifferently in many different parts of a plant. Many of them are very imperfectly known: they have nothing to do with the functions of vegetation, so far as we know; and it will be quite sufficient if we enumerate them in lists, under the heads of Acids, Alkalies, Neuter, Resinous, Tanning, and Colouring Principles.

Acids.—1. Ulmine, Ulmic, or Humic, which is also considered, with great probability, as being nothing more than the carbonaceous remains of dead vegetable matter; 2. Gallic; 3. Acetic, or Pyroligneous; 4. Malic; 5. Citric; 6. Pectic; 7. Rheic; 8. Krameric. 9. Ginkoic; 10. Glamic; 11. Lichenic; 12. Selenic; 13. Oxalic; 14. Tartaric; 15. Equisetic; 16. Moric; 17. Kinic; 18. Meconic; 19. Igasuric; 20. Abietic; 21. Pinic; 22. Sylvic; 23. Benzoic; 24. Kahinsic; 25. Phocenic; 26. Stearic; 27. Hydrocyanic, or Prussic; 28. Aspartic; and 29. Fungic.

Alkalies.—1. Delphine; 2. Aconitine; 3. Picrotoxine; 4. Morphine; 5. Sanguinarine; 6. Corydaline; 7. Violine; 8. Esculine; 9. Guaranine; 10. Brucine; 11. Coneine; 12. Quinine; 13. Cinchonine; 14. Strychnine; 15. Strychnochromine; 16. Solanine; 17. Nicotine; 18. Atropine; 19. Hyosciamine; 20. Daturine; 21. Daphnine; 22. Rhabarbarine; 23. Buxine; 24. Veratrine; 25. Smilacine.

Neuter Principles.—1. Gluten;

2. Vegetable Albumen, or Glutine; 3. Pollenine; 4. Berberine; 5. Asparagine; 6. Amygdaline; 7. Emetine; 8. Coffeine; 9. Narcotine; 10. Gentianine; 11. Plumbagine; 12. Amanitine; 13. Fungine; 14. Osmazome; 15. Adipocire; 16. Gelatine; 17. Fibrine.

Resinous Principles.—1. Polygaline; 2. Hesperidine; 3. Aurade; 4. Zanthopicrite; 5. Busurine; 6. Quassine; 7. Cathartine, 8. Coumarine; 9. Glycyrrhizine; 10. Caryophylline; 11. Coloquintine; 12. Elaterine; 13. Olivine; 14. Jalapine; 15. Digitaline; 16. Laurine; 17. Piperine; 18. Salicine; 19. Populine; 20. Corticine; 21. Abietine; 22. Scillitine; 23. Zeine.

Tanning Principle.—Tannin.

Colouring Principles.—1. Hematine; 2. Breziline; 3. Santaline; 4. Morin; 5. Fustel; 6. Quercitrine; 7. Orcanettine; 8. Alizarine; 9. Purpurine; 10. Xanthine; 11. Dragon's Blood; 12. Curcumine; 13. Luteoline; 14. Indigotine; 15. Pittacul; 16. Chromule; 17. Carthamine; 18. Polychroite; 19. Rheadine; 20. Varioline; 21. Orcine.

Chapter X.

Of Vegetable Excretions.

All the secretions hitherto spoken of are found in the inside of plants, and may be supposed to be innocuous, at least, if not useful, in the process of vegetation, as no attempt is ever made by plants to rid themselves of them, unless by accident.

There is another class, consisting of matters of various kinds, which would seem to be incompatible with the healthy being of vegetation, as we find them constantly thrown off on the outside of the root, or the stem and leaves, sometimes in the form of solid concretions, sometimes as viscid, or glairy, or other discharges, or most frequently as volatile emanations, which cause the various odours of the vegetable kingdom. These may be considered analogous to those parts of the food of animals which are voided, after having been deprived of their nutritious principles, and are therefore called excretions. We shall pass these rapidly in review, dwelling principally upon those of the roots, which seem to be the most important to man.

§ 1.—*From the Stem or Leaves.*

There is a plant common in gardens, called Fraxinella, whose leaves and stem are covered with little brown resinous glands, emitting a powerful balsamic odour. This plant, in warm weather, is surrounded by an inflammable atmosphere, formed by its own vapour, which will take fire when a light is applied to it, and produce a bright, rapid flame, which does no injury to the plant. It has been ascertained that this vapour is not hydrogen, but a volatile oil suspended in the atmosphere. Chenopodium vulvaria and several fragrant flowers have been found to give off pure ammoniac, and maritime plants are said to exhale chlorine.

Acid excretions are formed by the hairs of the Chick Pea, the Stagshorn Sumach, and some other species; and it is supposed that the singular property possessed by certain Lichens of immersing themselves in the calcareous rocks they inhabit, is owing to their excretion of oxalic acid.

The stinging power of the Nettle and similar plants is produced by an acrid matter which their hairs have the power of emitting when pressed, and which varies in intensity in different species. The Nettles of Europe simply produce an uneasy sensation, but some of those of India have brought on lock-jaw, and even death itself in torments; for the effect of their sting is represented to resemble boiling oil flowing over the part affected.

A discharge of *sticky* matter by the hairs, or simply by the surface, is of very common occurrence, especially by the former, which will be seen with minute drops of the excretion hanging from their points. It is this which gives their viscidity to such plants as the Rose Acacia, to the buds of the Horsechestnut, and the Tacamahac Poplar, and to the young leaves of the Birch tree. It is said to be in many cases chemically analogous to Birdlime.

Wax, or substances analogous to that production, and so called, is, in one shape or another, of very common occurrence on the surface of plants, and it exists even in their substance, as in pollen, some barks, &c. It forms the bloom of such fruit as the Plum and the Cucumber; it causes the glaucous appearance of Cabbages and Seakail, and produces the powdery efflorescence that is found on the surface of many Chenopodeous plants: in these cases it constitutes a coating which repels

water, so as to protect the parts from which it is excreted from the effect of humidity. In some instances wax is thrown off by plants in such considerable quantity, as to render the collection of it an object of trade. The Candleberry Myrtle (Myrica cerifera) has its berries guarded by a thick coat of vegetable wax; if thrown into boiling water, the wax is melted and floats, when it is skimmed off, and converted into candles of good quality; they are, however, green. The berries of this plant have been stated to furnish about one-ninth of their weight of wax. The Wax Palm (Ceroxylon Andicola) has its trunk covered with a thick coating of wax, which seems to ooze out from all parts of the surface both of the bark and leaves.

Sugar, or at least saccharine matter in a liquid state, is too well known in the form of the honey of flowers to require more than to be pointed out; in a solid form it is less common. We have it however in a crystalline state, secreted by the upper lip of the flowers of the Rhododendron Ponticum, and in the beak of Strelitzia; it exists upon the surface of a kind of Sea-weed called Fucus saccharinus, and it appears in large solid concretions as Manna. This substance, which is discharged in Europe chiefly by the Flowering Ash (Fraxinus ornus), either in consequence of wounds artificially inflicted on the branches, or of the punctures of insects, is produced by other plants in other countries. The Manna of Scripture is yielded by a species of Tamarisk, and by the Camel's-thorn (Alhagi Maurorum); it distils in India from a kind of Celastrus, and the common Larch furnishes a particular kind of Manna in no inconsiderable quantity.

In addition to the foregoing instances of excretions from the leaves or stems or flowers, there remains to be noticed the saline efflorescence of marine plants; a glairy substance which clothes the surface of submersed plants apparently for the purpose of protecting them from immediate contact with so active a solvent as water; discharges of insipid fluid from the points of the leaves of certain plants, especially of the Cæsalpinia pluviosa, a Brazilian tree which is said to produce a shower of drops of water resembling rain, and finally the pulpy matter which occurs in the inside of the seed-vessels of many fruits; the last-mentioned substance is an austere and acid fluid in Sophora Japonica; an opaque sub-acid pulp in the Tamarind, and an odoriferous stimulating juice in the Balsam of Tolu plant (Myrospermum toluiferum); in Cathartocarpus fistula it is a viscid purgative extract; in the Arnotta fruit it is a coloured powdery matter; in the common Quince it is a mucilaginous secretion, which covers the seeds; and there is a great many other kinds.

§ 2.—*From the Roots.*

That roots give off in some cases a peculiar matter, has been known for some time. Brugmans was the first to observe it in the Heartsease, and it was afterwards remarked in the Elm and some other plants. No one, however, seems to have suspected this to be a general function of vegetation before M. De Candolle, who as long ago as the year 1805 called attention to this curious subject. It now appears from experiments conducted by M. Macaire of Geneva, that to throw off excretions by the roots is a general property of plants, and one of their most important vital actions; that the matter so thrown off is in most cases deleterious to the species ejecting it, although it may be harmless to others, and that particular species discharge by their roots a matter so deleterious as actually to poison the soil. He found that Leguminous plants produce a substance analogous to gum, and a little carbonate of lime; grasses a minute quantity of matter containing certain alkaline and earthy muriates and carbonates, but very little gum; that Chicoraceous plants exude in abundance a brownish bitter excretion analogous to opium, and containing tannin, a gummy extractive brown matter, and certain salts; Papaveraceous plants a substance of a similar nature; Euphorbias a gummy resinous secretion of a yellowish white colour, and of an acrid flavour, and so on.

This fact probably explains why a plant will not generally succeed if planted in the earth which has been previously occupied by the same species. An apple-tree will not grow on the spot where an apple-tree has previously grown; wheat will not follow wheat, nor an oak-tree an oak; and this not from the soil being exhausted of nutritive principles, for the same effect will take place whatever the quantity of manure that is employed. This cir-

cumstance had always been inexplicable till the discovery of secretions from roots; for the old supposition that each plant was able to select its peculiar food from the soil, and so to exhaust it for itself, although not for others, was perfectly gratuitous. It now appears that, as roots absorb indifferently everything sufficiently fluid which is presented to them, when one species immediately follows another in the same soil, it is placed in the same situation as an animal compelled to feed upon its own excrement; and we know from experiment that they cannot bear that. For if you place a plant of Belladonna in a weak solution of extract of Belladonna, it is rapidly killed. The faculty indeed which plants possess of getting rid of the excretions of the roots would seem to be a necessary condition of their life; for if they had not such a power, the fæcal matter which they now part with would be redissolved by the ascending sap, and carried back into their system to their own destruction. Macaire showed by a simple experiment that a plant, if poisoned, will disembarrass itself of the offending matter by its roots if it has the opportunity. He took a plant of Mercury (Mercurialis annua), and divided its roots into two parcels, one of which he introduced into a weak solution of acetate of lead, and the other parcel into pure water; at the end of a few hours the water which was originally pure had become perceptibly impregnated with acetate of lead, which had therefore been taken into the circulation by the roots on one side of the plant, and thrown off again by the roots on the other.

Until a greater variety of experiments shall have been tried upon the nature and mutual action of excretions of this nature, it will be impossible to determine to what extent the discovery is of practical application. In the mean while it remains highly probable that it explains the cause of certain plants being considered weeds, or, as the French say, *mauvaises herbes*, that is, injurious to their neighbours; and that it will enable the scientific agriculturist to reduce to some intelligible laws the practice of farmers in regard to the succession of their crops, which is as yet entirely empirical. It moreover appears certain that it explains the cause of plants grown in pots, notwithstanding the quantity of manure that is given them, becoming unhealthy, unless their soil be frequently changed.

Chapter XI.

Flowering.

The foregoing Chapters will have explained by what means plants are nourished, and what the general result is of their nutritive action. The phenomena attendant upon flowering and fruiting have next to be considered.

The act of flowering or of expanding the flower is that which appears the most striking to ordinary observers, but it is in reality a mere preparation for the far more important act of reproduction. A great many highly-curious and interesting facts have been collected concerning it, but they are so little understood, their mutual connexion is so little apparent, and we are so far from comprehending their value in relation to other functions, that we shall occupy but little space in this treatise with their explanation.

Flowers are always prepared in the centre of the buds, or embosomed among the leaves for a considerable time before they expand. It is probable that the causes which conduce to dispose their parts to become sepals, petals, &c. instead of leaves, take effect at a very early period, when they are extremely rudimentary; but what the exact nature of those causes is we do not know. In general they are formed so rapidly, that a few months are sufficient to pass them through their larvæ state, but in certain Palms some years appear to be required. It is said that the rudiments of flowers may be discovered in the central bud of these plants as much, in some instances, as seven years before the perfect flowers expand. To watch the gradual change of the organs in such cases as these would be at once one of the most instructive and amusing inquiries in which a Botanist with leisure, opportunity, and good faith, could engage.

To what causes the production of flowers is owing is uncertain; it must generally be referred to the specific nature of plants, or what is called their idiosyncracy. Annuals, for instance, flower in a few weeks after their seeds are sown; what are called biennials demand some months; perennials a longer time, and trees several years: we know no more of the cause of this,

than of the cause of their being annuals, biennials, perennials, and trees. Some, again, blossom in the winter, as the Chimonanthus, the Christmas Rose, and the fragrant Coltsfoot; others in the earliest spring, as the Snowdrop, Adoxa, and the Crocus; while others, like certain species of Michaelmas Daisy, and the Chinese Chrysanthemum, cannot be made, by any known artificial means, to advance their autumn flowering even a few weeks. Plants, in short, have a periodicity of flowering varying in different species, which appears inherent in their own proper nature, and not capable of explanation upon any hypothesis worth mentioning.

The same is true of the hours at which they open their blossoms; one expands at dawn of day, another species a few hours later, a third at mid-day, some in the early evening, and a few when darkness has established her dominion. Hence, what are called the *Watches of Flora* have been constructed; tables in which every hour of the day is filled up by the expansion of some flower; but however useful these may be for comparing climate, they assuredly conduce in no degree whatever to elucidating the causes of the singular phenomena they represent.

Certain facts there are, however, which are deserving of notice, because they have a general application, and serve to throw light upon some of these obscure and unintelligible phenomena.

It would seem to be a general law that the quantity of flowers which a plant produces will be in proportion to the quantity of nutritious matter which that plant may be able to accumulate. If a Hyacinth is deprived of its leaves one year, it will not blossom the succeeding year; but if its leaves are so fully exposed to light and air that they go through their growth in uninterrupted health, and the flowers are destroyed for one year, the bulbs will blossom more finely than ever the succeeding year in consequence of the great quantity of nutritious matter that will have accumulated; for, in this case, not only is a sufficient quantity secreted by the leaves, but the stock prepared the previous year remains unexhausted in consequence of the flowers, which would have consumed it, having been destroyed. After hot and bright summers, when leaves have been in uninterrupted action, and a great quantity of solid matter has been deposited, as is obvious in the stunted state of the branches, a most abundant crop of blossoms is invariably the result; while the reverse takes place after cold and gloomy summers, which produce weak and watery shoots. Or if a tree is sterile, its branches may be made fertile by depriving them of a ring of bark near their insertion; this interrupts the backward flow of the sap, causes the nutritious secretions to collect above the annular incision, and thus brings on the formation of flowers. It is not improbable that this may be explained upon the supposition that when plants are in a state of slow growth, as in hot and dry summers, the appendages of the axis are retarded in their growth, fixed in whorls, and receive a tendency to imperfect development which will inevitably produce flowers; while, on the contrary, no arrestation of growth, nor any fixing in whorls, will take place when plants are in a state of constant and rapid growth, and consequently nothing but leaves will be the result. This will be the better understood by a reference to the laws of Morphology (Chap. XXV., Part I.); and is, to a certain extent, illustrated by a fact well known to all observing gardeners, that, in wet and warm springs, a great number of the blossom buds of Pears and Apples are converted into leaf-buds by the excessively rapid development which they undergo breaking up the whorls of their flowers, throwing an excessive quantity of sap into the organs which had been destined for flowering purposes, and thus converting them into leaves.

There is also another fact which seems to show that flowering depends upon the accumulation of a sufficient quantity of nutritive matter in the part which is to flower. An Apple when raised from seed, and left to unassisted Nature, will not flower in less than on an average seven years. But if a cutting of it, one year old, be grafted upon an old bearing tree, which is able to infuse into it a large quantity of nutritive matter, it will bear the second year after being grafted; so that by this means in three years at the latest a plant may be artificially made to bear, which, under ordinary circumstances, would not flower in less than seven at the soonest.

The mere act of flowering is a pre-

paration for fertilization, with reference to which it is principally important, and in relation to which some other circumstances will be spoken of. As soon as fertilization is accomplished, a new being, the embryo, is called into existence, which attracts to itself all the nutritive matter that was before conducted to the sepals, petals, and stamens; the latter then shrivel up, and the act of flowering is accomplished. There are, however, some curious exceptions to this rule. In many plants the sepals continue to grow after fertilization has taken place. In others, as the Burmese Varnish Tree (Melanorrhœa) the petals become excessively enlarged; but the stamens uniformly perish.

For the amusement of those who are interested in such matters, we subjoin a *Watch of Flora*,—that is, the hour of expansion of various flowers, as it is recorded by Linnæus for Upsal, and by De Candolle for Paris :—

Name of Plant.	Upsal.	Paris.
Convolvulus nil and sepium	..	3–4 a.m.
Tragopogon pratense . .	3–5 a.m.	4–5 a.m.
Other Cichoraceous plants	4–5 do.	do.
Matricaria suaveolens. .	...	do.
Crepis tectorum . . .	4–5 a.m.	...
Papaver nudicaule . .	5 a.m.	5 a.m.
Moist Cichoraceæ . .	...	do.
Momordica elaterium . .	...	5–6 a.m.
Lapsana communis, and many Cichoraceous plants	5–6 a.m.	do.
Convolvulus tricolor . .	...	do.
Hypochæris maculata .	6 a.m.	6 a.m.
Solanum, several species	...	do.
Convolvulus Siculus . .	...	do.
Sonchus, different species	6–7 a.m.	6–7 a.m.
Hieracium, do. . . .	6–7 a.m.	do.
Nuphar and Nymphæa .	7	7 a.m.
Lactuca sativa . . .	...	do.
Camelina sativa . . .	...	do.
Prenanthes muralis . .	...	do.
Mesembryanthemum barbatum	...	7–8 a.m.
Specularia speculum . .	...	do.
Cucumis anguria . .	...	do.
Calendula pluvialis . .	7 a.m.	do.
Anagallis arvenesis . .	8	8 a.m.
Dianthus prolifer . .	8	...
Nolana prostrata . . .	...	8–9
Hieracium chondrilloides	9	..
Calendula arvensis . .	9	...
Mesembryanthemum barbatum, &c.	7–8	...
Mesembryanthemum crystallinum	9–10	9–10
Arenaria	9–10	...
Mesembryanthemum nodiflorum	10–11	10–11
Portulaca sativa . . .	...	11
Ornithogalum umbellatum (called on that account Dame d'onze heures)	..	11
Tigridia pavonia . . .	...	do.
Most Ficoideous plants .	...	12
Scilla pomeridiana . .	...	2 p.m.
Silene noctiflora . . .	9–10	5–6
Mirabilis jalapa . . .	5	6–7
Pelargonium triste . .	6	...
Cereus grandiflorus . .	9–10	7–8
Mesembryanthemum noctiflorum	...	do.
Œnothera tetraptera . .	...	do.
———— suaveolens . .	...	do.
Convolvulus purpureus .	...	10 p.m.

Chapter XII.

Fertilization.

Upon looking to the writings of ancient authors, we find that, from a very early period, the world was acquainted with two cases in which the presence of flowers of a particular kind was necessary to ensure the fertilization of another kind borne by the same species, ultimately bearing fruit if fertilization was effected; but remaining sterile provided the flowers of the first kind were not permitted to exercise their influence. One of these cases was the Date Palm, the other was the Fig.

Man had learned from experience that those flowers of the Date, in which the beginning of a fruit was discoverable, would never arrive at maturity unless sprinkled with the powder secreted in the flowers of other individuals of the same species of Palm: and hence they considered the latter to be males and the former females; which was true. Wild Figs again were found to be necessary, by coming in contact with it, to enable the fruit of the cultivated Fig to mature; and hence they also supposed the former to be males and the latter to be females, which, however, was *not* true. Caprification, as this latter phenomenon was termed, did not depend upon the powder of the wild Fig coming in contact with the young fruit of the cultivated Fig, but upon a totally different circumstance; for both kinds of Fig are in reality perfect in themselves. What makes the act of caprification necessary is this,—that the flowers of a Fig are inclosed in a fleshy case, which finally becomes the fruit, and, from some unknown cause, does not readily ripen unless injured by the puncture of an insect.

The Wild Fig abounds in a little fly called a Cynips; and, consequently, when the former is brought into the vicinity of the cultivated Fig, the latter is attacked by the Cynips, and so enabled to mature. It is clear from their having confounded, under the same idea, two phenomena so essentially different as these, that the ancients had no real knowledge of the sexes of plants; and it is probable that all their notions were deduced from hypothetical considerations arising out of the comparison drawn by their philosophers between plants and animals, than from any exact knowledge which they possessed.

Nor, indeed, is there any reason to believe that the discovery of the sexes in plants, as a general fact, can be traced farther back than the time of Sir Thos. Millington, Green, Malpighi, and Ray. The latter said in express terms, in the year 1694, that the points of the stamen are the most essential parts of a flower, as they contain pollen, which, in his opinion, is endowed with a prolific power, and serves to fertilize the seeds. From this time the question was settled among botanists, notwithstanding the captious objections of a few writers whose names and opinions have alike sunk in oblivion. It was Linnæus, however, who brought the subject more particularly before the world, in consequence of his having employed the sexes of plants as the basis of his classification; and although, in point of fact, this writer added little, or nothing to what was before known, and even by his speculations upon hybrid plants rather tended to weaken the theory in the eyes of men of science, yet the attractions of his style, and the skill with which he embellished the subject, were such, that the vulgar believe him to have been the discoverer of the existence of vegetable sexuality. From his time to the present every succeeding observation has tended to confirm this curious fact; and the mass of evidence is now so great, that no one thinks of calling its truth in question as a general law of Nature.

In fact, if the thing is considered a little, we find on all sides the clearest evidence that seeds cannot be fertilized without the contact of pollen and stigma. We select a few of the most striking. Maize is a kind of corn, the anthers of which are formed in the loose panicles that terminate the stem; the styles, with their stigmas, are the long silken tassels which hang down from the short branches near the base of the stem. If the panicles are destroyed, the stigmas are not fertilized, and no grain is produced. Take an Apple-blossom, and cut out the anthers before the anthers burst; no apple will be formed. Let the stamens be all converted into petals, as in double flowers, and the pistils are barren, however perfect they themselves may be. In a Cucumber plant some of the flowers bear nothing but stamens, and others contain nothing but pistils. If the former are carefully cut away, the latter, instead of swelling immediately after the flower has withered, will become yellow, cease growing, and suddenly drop off. We are therefore surrounded by proofs of the necessity of the anthers to fertilize the pistils.

Nevertheless, as in some animals, so in some plants, it appears that parts analogous to flowers produce fertile bodies, resembling seeds in their power of reproducing the species, without there being any trace of anthers. This occurs in Ferns, Fungi, Lichens, Seaweeds, and, in all probability, in every tribe of flowerless plants. This fact has led some botanists to deny the necessity of anthers in species where they are regularly produced. It has been asserted that the Basil (Ocymum), Hemp, and Spinach will produce fertile seeds without coming in contact with the pollen; but while this is asserted by one observer it is denied by another, and appears altogether so contrary to common sense as to be undeserving any further remark than this, —that in those species anthers are regularly produced, as perfect in their structure as in any plants whatever; and that it is not probable they would be so produced unless they had their usual office to perform. Are we to believe that no sexes exist in the animal kingdom because the Aphis is increased without their aid? Passing by, then, these speculations, let us look at the highly-curious phenomena of fertilization, as understood by the best observers.

When the flower unfolds, the anther is a tolerably solid, moist body, filled with moist pollen. The grains of the latter contain a fluid more dense than the tissue that forms a covering for them, and rapidly absorb its moisture from the anther case. As soon as this

has happened to any great extent, the tissue of the anther case contracts, and at first rends into grated cells of various forms; as the dryness is increased, these latter contract still further, and exercising a general power over the whole surface of the lining, would, in the end, be rent into still finer portions, if it were not for the slight degree of cohesion which exists between the valves of the anther at the sutural line. Here, then, the lateral strain of the contracting cells compels the anther to open, and the pollen is enabled to fall out.

At the same time that this is going on in the anther, the tissue of the stigma is becoming more and more lax, and secreting a viscid fluid between its cells; so that by the time the pollen is discharged from the anther, the stigma has become an uneven, clammy surface, with prominent cells, between which any foreign matter can be easily insinuated.

Upon the stigma thus prepared the grains of pollen either drop or are cast, or are conveyed by wind, insects, or other means; and there they are secured by the clamminess of the organ.

When the grains of pollen have lain upon the stigma for several hours they open at their angles, or upon certain definite points of their surface, and the thin inner lining, which is of a highly-extensible nature, is gradually prolonged into extremely slender intestines, called *pollen-tubes*, which sink into the tissue of the stigma, burying themselves within it, just as the roots of a plant bury themselves in the soil.

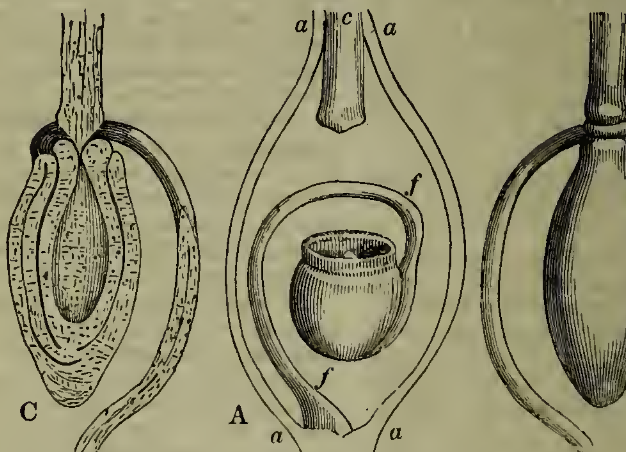
By means of the pollen-tubes the matter contained in the pollen-grains is conveyed into the interior of the style, whence it is supposed to pass into the ovule. This matter has been already (p. 42) described as consisting of round and oblong minute particles floating in liquid; and it is believed that the fertilizing principle, be it what it may, resides in those particles,—perhaps only in the larger kind, perhaps in the smaller—possibly in both. In general, it is very difficult to see the pollen-tubes; for if the pollen rubs freely from the surface of the stigma, the tubes are not emitted; if it is removed with difficulty, the tubes are broken off. They may, however, be easily seen in any Gesnera, by scraping from off the stigma pollen that has been in contact with it at least forty-eight hours. The Crocus also parts with its pollen-tubes easily; and if a minute portion of the stigma of Crocus vernus is pressed gently in water between two plates of glass till it is transparent, the pollen-tubes will be distinctly seen buried in the stigma, with the turbid matter of the pollen lying in unequal quantities in their inside. Amici recommends the Althæa frutex for the same observation; but that plant is not well adapted for examination, because in this northern climate its pollen is rarely perfect. Should a difficulty be after all experienced in witnessing these singular phenomena, it may be brought about artificially by the following simple means. Place a drop of a solution of concentrated sulphuric acid and water, in the proportion of two parts of the former to three of the latter, upon the stage of a microscope; drop into it a few grains of pollen, then watch them, and they may be seen to become rapidly transparent, to give way at the angles, or at some particular points of their surface, and to emit their pollen-tubes just as they would, only much more slowly, under the natural stimulus of the secretion of the stigma.

To what distance the pollen-tubes descend into the style is, in most cases, a matter of conjecture. But from the observations of several accurate microscopical observers, especially of Dr. Brown, it can scarcely be doubted that they are not only actually conveyed to the placenta, but are introduced into the ovules. This distinguished Botanist confirms the statement of Du Petit Thouars, that a cord developed in the stigma of Orchideous plants may be traced to the placentæ and consequently to the ovules; and he declares that this cord is entirely composed of pollen-tubes. He found the branches of the cord scattered over the whole surface of the placentæ in Orchis Morio; and he even succeeded in tracing in several, though not in many instances, a single tube to the foramen of an ovule. He was also so fortunate as to witness the same phenomenon in many cases in Habenaria viridis. Adolphe Brongniart also describes the pollen-tubes in the Rock Rose (Helianthemum) as entering the cavity of the ovary, and descending from its summit till they reach the ovules.

In connexion with these phenomena, there is another class of actions on the part of the ovules which it is important to be aware of. In many cases it has

been seen, and it is probable that in all cases it happens that at the time when pollen-tubes are plunged into the stigma, the ovules adjust themselves so as to present their foramen either to the placenta, or else to that point of the lining of the ovary by which the pollen-tubes afterwards enter. This is plainly the case in the Rock Roses just referred to; in Euphorbias it may also be witnessed; and the very act of curving which takes place in so many ovules, as has already been mentioned (p. 46, *fig.* 61), is no doubt for the purpose of effecting the same object. If we examine the ovule of the Spurge Laurel (Daphne Laureola), before the pollen falls upon the stigma, we shall find its foramen turned towards the dome of the ovary, but far from touching it. Soon after the pollen has acted upon the stigma the ovule approaches the dome, a short process in direct communication with the stigma is at the same time protruded from the dome, and finally closes up the foramen, thus bringing the nucleus of the ovule in direct organic communication with the stigma. A similar case of rather a more complicated kind, and not so easily witnessed as the last, occurs in the Thrift plant (Armeria vulgaris), *fig.* 100.

Fig. 100.



Let the ellipse *a a*, *fig.* A, represent a section of the ovary of this plant. From its base there arises an umbilical cord *f f*, which curves after reaching about half the length of the cavity, and bending down upon itself again turns partially up, bearing an ovule at its apex. When very young this ovule is a sort of cup, the mouth of which is closed by a little cone, and is turned towards the apex of the ovary. From all access to the dome of the ovary the ovule is cut off, notwithstanding its position, by the cord which over against the aperture of the ovule spreads into a kind of strap. It is from the point of the ovary *c*, that the stigmas arise; and from immediately below their origin a short cylinder projects down into the cavity of the ovary. Matters being thus arranged, the pollen falls upon the stigma, and pollen tubes are forced into its tissue and gradually find their way into the cylinder; at the same time the ovule lengthens, contracts at its aperture, and is brought near the cylinder by the elevation of its umbilical cord; at last the strap is slipped aside, the cylinder lengthens, the ovule rises, and with its aperture embraces the point of the cylinder, which is somewhat conical, and which is thus brought into contact with the nucleus. At this time the parts are in the position represented at *fig.* B; and if cut through longitudinally, as at C, they will be seen to be placed in the most favourable position that can be imagined for enabling any fertilizing matter that may have been communicated to the stigma to find its way into the interior of the ovule.

What the nature is of the communication thus made by the pollen to the ovule through the medium of the pollen-tubes, the result of which is fertilization, we have no means of knowing. It may either be a peculiar stimulus which is required to call into existence an embryo germ of life residing in the point of the nucleus; or it may be the act of conveying such a germ to the

nucleus from out of the pollen grains. Opinions are divided upon these points, and they are likely to remain so; for we can conceive no means of solving the problem. It may, however, be remarked, that Dr. Brown declares that he could not discover the pollen-tubes of Orchideæ, even in their earliest stage, while in length hardly equal to the diameter of the grain, to contain distinct granules; and that when, with a magnifying power of 300 or 400, minute and very transparent granular matter came into view, it was extremely different from the granules of the pollen-grains. As it is not improbable that this may be a special and not a general case, and that it is connected with the peculiar structure of Orchideous plants, we do not think much stress ought to be laid upon it in the present state of our knowledge; especially as pollen-tubes do, in other instances, most unquestionably contain the molecular matter of the pollen-grain, whatever the functions of that matter may be considered to be.

The principal difficulties in the way of admitting actual contact between the pollen and the stigma to be indispensable to fertilization, exist in Orchideous and Asclepiadeous plants; in both which Nature seems to have taken infinite pains to prevent such contact. In the former, in particular, there are many cases in which actual contact seems physically impossible, and there are others in which it is very improbable; and although the pollen when placed upon the stigma is undoubtedly capable of producing its tubes, yet as molecular matter cannot be detected in them, it may be doubtful whether the pollen-tubes when developed are not rudimentary organs. Several botanists, and particularly Mr. Bauer, believe that fertilization takes place in these plants by some peculiar mode of internal communication; but whatever may be the fact with regard to Orchideous plants, none can now remain in regard to Asclepiadeous plants, after the luminous explanations of the manner in which it is effected which have appeared within these few years, especially from Ehrenberg, Brown, and Adolphe Brongniart.

In these plants the stigma is a fleshy five-cornered disk, having a gland (*fig.* 101, *d*) at each angle. To each gland is attached a pair of yellow bags (*b*) containing the pollen, and called *pollen masses;* which are more convex on one edge than on the other. The stigma itself has no visible secreting surface; and as the pollen masses had never been seen to discharge the pollen grains, it was supposed that fertilization must be in this case effected by some internal communication through the glands. But Ehrenberg proved that the grains of pollen produce pollen-tubes all directed towards the most convex edge of the pollen mass, which is also the thinnest, and that they are eventually forced through it. Brown and Brongniart, pursuing this fact, instituted some very careful observations upon the sub-

Fig. 101

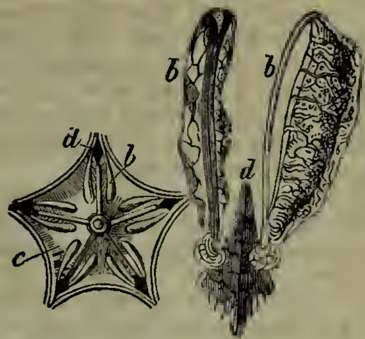
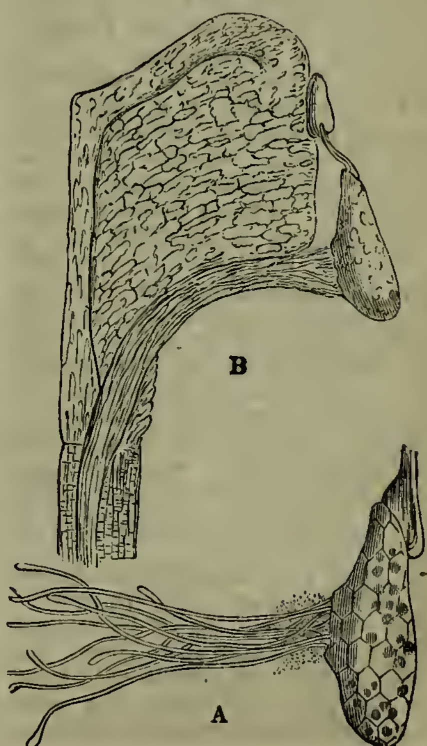


Fig. 102.



ject, the result of which proved not only that pollen tubes are emitted by Asclepiadeous plants, but that they bury themselves in the stigma just as in other plants, and as is represented at *fig.* 102, where A represents a pollen mass with its pollen-tubes protruded, and B shows the manner in which they are introduced into the stigma.

From these circumstances we may conclude, that in the fertilization of plants pollen falls upon the stigma and inserts a tube into its tissue; that the tube reaches the aperture of the ovule; and that unless this happens fertilization is not accomplished. We must here dismiss this curious subject, leaving many most interesting facts untold, and proceed at once to other matter.

Chapter XIII.

Of the Temperature of Flowers.

If we test the temperature of a flower, however large it may be, it is extremely probable that we shall discover no difference whatever between it and the external air. And yet it appears certain from well-attested observations, and probably from theory, that flowers have at certain periods of the day a temperature much elevated above that of the air which surrounds them. Lamarck found the spadix of Arum Italicum perceptibly warm; and De Candolle ascertained at Montpellier, that the elevation of temperature commences about three o'clock P. M., gains its maximum at five P.M., and ceases altogether at seven. Senebier found the common Arum seven degrees warmer than the air. Schultz found the spadix of Caladium pinnatifidum four or five degrees warmer than the air; others have ascertained the same part in Arum cordifolium to acquire as much as thirty degrees of temperature above that of the air at sun-rise; and finally, Theodore de Saussure assured himself that even in the Gourd, and other common plants, the temperature rises half a centigrade degree. The fact being thus incontestable, it is interesting to see in what way it is conformable to theory.

It is well known that the petals and all other *coloured* parts (p. 90) of plants deprive the air of its oxygen, which combines with their carbon and forms carbonic acid: that this takes place at particular hours to a great extent, as is evident from the following table of the result of some experiments made by Theodore de Saussure upon the proportion of oxygen consumed by plants in proportion to their volume, when placed in receivers of atmospheric air over mercury; the experiment lasting twenty-four hours, and the external temperature being between 18° and 25° centigrade.

	Oxygen consumed by Flowers.	Leaves.
Common Stock, single red var.	11	4
Ditto, double	7·7	
Tuberose, single	9	3
Ditto, double	7·4	
Brugmansia arborea	9	5
Passiflora serratifolia	18·5	5·25
Hibiscus speciosus	8·7	5·1
Gourd, sterile Flowers	12	6·7
White Lily	5	2·5
Typha	9·8	4·25
&c. &c. &c.		

It was also ascertained that the stamens and pistils are still more rapacious of oxygen. Those of the Stock consumed 18 times their volume instead of 11½; of the Nasturtium, 16·3 instead of 8·5; and of the Gourd, 16 instead of 7·6. But it was found that this takes place to the most considerable extent in Arums. While the spathe of the common Arum consumed only 5 times its volume of oxygen, its spadix destroyed 30 times, and that part on which the stamens and pistils are placed as much as 32 times.

Hence it would seem that the high temperature of flowers is owing to the combination of oxygen and carbon, which produces a kind of combustion; and if so, we ought to find signs of disengagement of caloric by all flowers. It is, however, to be remembered, that in by far the greater number of flowers the heat is carried off by the atmosphere the instant it is disengaged, and that it is only where flowers are collected in great numbers within cases which act as non-conductors and confine the heat, as happens in Arums, that the elevation of temperature becomes appreciable.

Chapter XIV

Of Fruiting.

Immediately after fertilization has taken place, all the parts of the ovary swell, the ovule closes its aperture, the stigma loses its humidity, the vessels of the style collapse, and the latter organ either drops off or hardens upon

the ovary as a rigid process; while at the same time an embryo plant develópes in the inside of the ovule. This latter occurrence never supervenes unless the act of fertilization is accomplished; all the others may take place, the ovary may grow, and even the integuments may acquire their mature dimensions, in the absence of it.

In by far the greater number of cases, the pericarp becomes more and more leathery, woody, cartilaginous, or membranous, and gradually changes from green to brown or white; and in such cases the world is scarcely conscious of the production of fruit. But in some instances the pericarp acquires a greater volume, becomes succulent instead of drying up, often acquires the gayest colours, and in time becomes what we popularly term fruit, that is, a body which may be eaten, or looks as if it might. It is said that, in the former of these cases, the surface of the fruit abounds in stomates, which enable the fluid matter of the pericarp to be freely evaporated, and that in the latter an absence of stomates causes the fluid matter to accumulate; but it is to be suspected that there is more hypothesis than truth in this speculation. Be that however as it may, it is with the latter class of fruits that the world is most conversant, and in which it is most interested, and to which it is therefore most desirable that we should turn our attention. We will consider them, firstly, as to their action upon the atmosphere, and secondly, as to the nature of the changes which lead them, from being acid, austere bodies, to become the rich, sweet, fragrant, and often luscious productions, which we find in the Peach, the Orange, the Fig, the Grape, and the like.

With reference to the first of these considerations, the words of Theodore de Saussure are the only ones which it is necessary to quote. "Fruits, while green, whether leafy or fleshy," says this great observer, "act much as leaves either in the sun or in shade, and differ from those organs principally in the intensity of their action. In the night they destroy the oxygen of their atmosphere, and replace it with carbonic acid, which they partially absorb again. This absorption is generally less in the open air than under a receiver; and their volume remaining the same, they consume more oxygen in darkness when distant from ripeness than when they are approaching that state. If exposed to the sun, they disengage altogether or in part the oxygen which they inspired during the night, and preserve no trace of this acid in their own atmosphere. If many fruits are detached from the plant, they thus add oxygen to air which contains no carbonic acid. When their vegetation is very feeble, or extremely languid, they vitiate the air under all circumstances, but less in the sun than in the shade. Green fruits detached from a plant, and exposed successively to the action of the sun and of darkness, change it but little or not at all either in purity or in volume. The trifling variations that may be remarked in this respect depend either upon the greater or less faculty which they have of elaborating carbonic acid, or in their composition, which is modified according to the degree of their ripeness. Thus Grapes in a state of verjuice appear to assimilate in small quantity the oxygen of the carbonic acid which they form in the air where they vegetate both day and night; while, on the contrary, Grapes nearly ripe give back almost entirely during the day to their own atmosphere the oxygen of the carbonic acid they have formed in darkness. If there is no deception in this circumstance, which, although feeble, appears to have been constant, it marks the passage from the acid to the sweet state by indicating that the acidity of verjuice depends upon the fixing of the oxygen of the air, and that this acidity disappears when the fruit no longer seeks for carbon in the air or in carbonic acid. Green fruits decompose either entirely or in part not only the carbonic acid they have produced during the night, but in addition such quantity as may be artificially added to their atmosphere. When this last experiment is tried with fruits which are not watery, and which, like Apples and Grapes, elaborate but slowly carbonic acid, one sees that they absorb in the sun a much larger proportion of gas than the same volume of water in a similar mixture; afterwards they disengage the oxygen of the carbonic acid absorbed, and thus appear to elaborate it in their interior.

"They appropriate to themselves during their vegetation both oxygen and water, compelling the latter to lose its liquid state.

"These results are often not observ

able in volumes of air less than from 30 to 40 times that of the volume of the fruit, and by diminishing the heating power of the sun. If such precautions are neglected, many fruits will vitiate the air even in the sun by forming carbonic acid with the ambient oxygen; but even in the latter case, the simple comparison of their effect in light with what they produce under the influence of night and darkness, demonstrates that they decompose carbonic acid."

With regard to the alterations which the constituent parts of fruit undergo during the action of the preceding phenomena, and in the course of maturation, we cannot do better than reproduce the results obtained by De Candolle, from the observations of Bérard of Montpelier.

If we examine the modifications which the flesh of fruits undergoes in ripening, we shall at first remark that their fibrous or cellular tissue (which varies very much in quantity in different species) is merely lignine. In most cases, especially in very fleshy fruits, lighter, less tough, and more easily soluble in alkaline solutions than common lignine; but presenting characters of an opposite kind in other parts of the same fruit, such as their stones.

The liquid which fills the flesh of succulent pericarps consists of sap placed in the inter-cellular passages and of the matter contained in the cells. This liquid of the flesh, or of the fleshy endocarp, contains, besides a great quantity of water, sugar, gum, malic acid, malate of lime, colouring matter, a vegeto-animal substance, and an aromatic secretion peculiar to each fruit: there is, moreover, in certain cases, the tartrates both of potash and of lime, as in Grapes; and citric acid in the Lemon, and even in small quantity in the Gooseberry.

A comparison of the analysis of certain fruits before they are ripe and at that period gives some curious results. In the first place there is a disappearance of water in a liquid state, viz. per cent.—

	Water before ripeness.	Water at ripeness.
Apricots	89·39	74·87
Currants	86·41	81·10
Duke Cherries	88·28	74·85
Green Gages	74·87	71·10
Melting Peaches	90·31	80·24
Jargonelle Pears	86·28	83·88

This diminution appears to depend in part upon the fruit absorbing less water as it approaches maturity and in part upon the combination with its tissue of a portion of the water it has received. Sugar, on the contrary, appears to be continually on the increase, as indeed the taste would tell us; thus we find, per cent.,—

	Green.	Ripe.
Apricots (a trace when young, afterwards)	6·64	16·48
Red Currants	0·52	6·24
Duke Cherries	1·12	19·12
Green Gage Plums	17·71	24·81
Melting Peaches	0·63	11·61
Jargonelle Pears	6·43	11·52

This sugar is sometimes in a state more or less concrete, as in the Grape, the Fig, and the Peach, sometimes in a liquid state. It seems to be formed at the expense of other matters, the proportion of which diminishes. Thus the quantity of lignine per cent. is found—

	Green.	Ripe.
Apricots	3·61	1·86
Currants (including the seeds)	8·45	8·01
Duke Cherries	2·44	1·12
Green Gage Plums	1·26	1·11
Melting Peaches	3·01	1·21
Jargonelle Pears	3·80	2·19

It is possible, indeed, that the lignine formed in the green fruit did not in reality diminish, but that the dilatation of the cellular tissue, and consequently the augmentation of the aqueous products rendered it proportionably less, without its being absolutely so. But the gummy, mucilaginous, or gelatinous matters, appear very susceptible of changing into sugar: thus, M. Couverchel has found that if we treat apple jelly with a vegetable acid dissolved in water, we obtain a sugar analogous to that of Grapes; that the gum of Peas, placed with oxalic acid, in a temperature of 125° (Réaum.) changed to sugar; that gum extracted from starch, if mixed with the juice of green Grapes, rendered the latter saccharine; and finally that tartaric acid will produce the same effect by aid of heat: this is the reason why most fruits become sweet when cooked.

Other matters offer remarkable disparities between one fruit and another: thus malic acid keeps diminishing in Apricots and Pears, augmenting in Currants, Cherries, Plums, and Peaches. Gum keeps diminishing in Currants,

Cherries, Plums, and Pears, and augmenting in Apricots and Peaches. Animal matter keeps diminishing in Apricots and Plums, and increasing in Currants, Peaches, Cherries, and Pears. Lime, which never exists except in small quantity, seems generally to diminish, probably because evaporation becomes less with maturity.

With regard to the alterations which fruits undergo after ripening, in most instances decaying and in others bletting, there are several circumstances deserving of attention. These two states of decomposition cannot, according to Bérard, take place except by the action of the oxygen of the air, although he admits that a very small quantity only is sufficient to cause it. He succeeded in preserving for several months, with little alteration, the fleshy fruits which were the subjects of the foregoing experiments, by placing them in hydrogen or nitrogen gases. All fruits at this extreme period of their duration, whether they decay or whether they blet, form carbonic acid with their own carbon and the oxygen of the air, and moreover disengage from their proper substance a certain quantity of carbonic acid.

Bletting is in particular a special alteration; it appears that the more austere a fruit is before this is brought on, the more it is capable of bletting regularly. It has been found that a Jargonelle Pear in passing to this state loses a great deal of water (83·88 reduced to 62·73), pretty much sugar (11·52 reduced to 8·77), and a little lignine (2·19 reduced to 1·85); but acquires rather more malic acid, gum and animal matter. Lignine, in particular, seems in this kind of alteration to undergo a change analogous to that of wood in decay.

With regard to the ripening of seeds, it may be remarked that in all cases the first thing that occurs after fertilization is the closing up of the aperture of the ovule; next to which comes the appearance of the embryo, which is originally an opaque speck near the apex of the nucleus, and which at that time is surrounded by a mucous fluid, from which it seems to derive its nutriment. Although in many cases no trace is finally discoverable of a chord connecting the embryo with the point of the nucleus, yet in some instances such a communication is plainly visible, as in Zamia and Cycas, and according to Brown in Orchideous plants. As the embryo advances in size, it projects forwards into the cavity of the ovule, absorbing the fluid-matter which bathes it, till, when it is finally ripe, there is no longer any water in an unfixed state. During the solidification of its parts it gradually exchanges its saccharine quality, which seems common to all seeds when young, for the amylaceous, oily, resinous, and other secretions which are peculiar to it. It also deposits among its tissue a variable quantity of earthy matter, and of carbon, which contributes to give it a certain degree of hardness, which in some instances is of a stony consistence. All this accomplished, it acquires a greater weight than water, and consequently if ripe seeds are thrown into that fluid they will sink if they are properly matured, unless, as happens in some cases, the integuments of the seed contain air-cells, or there should be a cavity in the centre of the seed itself.

Although the deposition of earthy or other solid matter is what marks the complete maturity of a seed, yet it appears that this condition is not necessary to secure germination, for Senebier found that unripe Peas vegetated more freely than ripe ones. It rather appears to be a provision of nature to protect them from accidents, and to enable them to resist in safety the many vicissitudes they are likely to experience, after having once separated from their parent plant.

It appears, indeed, as if the longevity of seeds, that is to say the length of time they can preserve their vegetative powers, depends very much upon the completeness of the protection afforded the embryo by its integuments. Gardeners know how impossible it is to preserve very delicate seeds with thin skins more than a few weeks or months; while, on the other hand, hard, bony seeds have been known to germinate after the lapse of a great number of years. When land is cleared, or ancient ditches emptied, or earth broken up to a considerable depth, as in well-digging, it not unfrequently happens that plants spring from the mould, whose seeds must have been buried for many years or ages. Even when exposed to the vicissitudes of climate, seeds will often grow after many years; seeds of melons have been known to grow after forty-one

years, Indian Wheat after thirty years, Rye after forty years, Sensitive Plant after sixty years, and Kidney Beans, taken from Tournefort's herbarium, a hundred years after they were gathered.

It is extremely difficult to say what the conditions are under which the vitality of seeds is thus preserved, so conflicting are the statements of cultivators, and so little apparent connexion have the instances of seminal longevity with each other. It may, however, upon the whole, be inferred from the duration of seeds buried in the earth, and from other circumstances, that the principal conditions are, 1. uniform temperature ; 2. moderate dryness ; and 3. exclusion of light. And it will be found that the success with which seeds are transported from foreign countries in a living state is in proportion to the care and skill with which these conditions are preserved. For example, seeds brought from India, round the Cape of Good Hope, rarely vegetate freely ; in this case the double exposure to the heat of the equator, and the subsequent arrival of the seeds in cold latitudes, are probably the causes of their death, for seeds brought overland from India, and therefore not exposed to such fluctuations of temperature, generally succeed. Others, again, which cannot be conveyed with certainty if exposed to the air, will travel in safety for many months if buried in clay rammed hard in boxes ; in this manner only can the seeds of the Mango be brought alive from the West Indies ; and it was thus the principal part of the Araucaria Pines, now in England, were transported from Chile. It may therefore be well worth consideration whether, by some artificial contrivance, in which these principles shall be kept in view, it may not be possible to reduce to something like certainty the preservation of seeds in long voyages. Such, for instance, as by surrounding them by many layers of non-conducting matter: as case over case of wood ; or by ramming every other space in such cases with clay in a dry state. These means seem more likely to answer their end than the usual modes of putting seeds in bottles, packing them in charcoal, or surrounding them by coats of wax—all of which, it is well known, are absolutely prejudicial, instead of beneficial to the seeds. In illustration of what we have recommended, we may add that seeds are well known to travel best in their own pods, or pericarps ; may we not suppose that their vitality is preserved in such instances by the non-conducting quality of the air which the cavities of the fruit contain ?

Chapter XV.

Of Germination.

When a plant has ripened its fruit and fully formed its seeds, it has, to a great extent, fulfilled its destiny, and it has accomplished the important act of reproducing its like. It will by that time have gone through all the phases of growth, and to whatever number of years it may afterwards exist, its life will be only a repetition of phenomena that have already occurred to it.

The act of germination, therefore, which is the springing into life of a new individual, is to be considered the first period of growth, and the commencement of a future system, not the termination of an old one, as might be supposed from the subject being mentioned thus late in the present sketch.

A seed when beginning to grow presents the following remarkable features. If placed in a humid medium, and exposed to a moderate degree of warmth, it absorbs the ambient fluid, distends, bursts its integuments, protrudes a root downwards into the earth, and shortly after elevates a stem into the air. This is all that strikes the ordinary observer ; but if the seed be examined more carefully, it will be found to absorb oxygen from the air that surrounds it, and to give off carbonic acid in considerable quantity. By this means it gets rid of the carbon of which it originally consists in a high degree, and its parts are softened by water and rendered more capable of extension and expansion. If a seed is made to germinate in light this happens in a less degree ; but in light or in darkness it happens always. Such being the case, and such the struggle on the part of the seed to get rid of its carbon by converting it into carbonic acid, we may con clude that whatever favours or impedes the destruction of carbon during germination will be advantageous or the contrary to the function. And this explains the cause of seeds buried at great depths beneath the soil, where they are cut off from communication with the oxygen of the atmosphere,

remaining for so many years without germinating. In fact it has been ascertained by experiment, that if seeds are placed either *in vacuo*, or in an atmosphere of nitrogen or hydrogen, they will not germinate; and still less in carbonic acid. It is a remarkable circumstance, and one which is of no little interest in pointing out the wonderful foresight with which every part of the creation is adapted to mundane conditions, that after many trials it has been found that seeds germinate most freely in an atmosphere consisting of one part oxygen and three parts nitrogen, which is nearly the proportion of the air we breathe. If the quantity of oxygen is increased, the carbon of the embryo is abstracted too rapidly, and the young plant is feeble; if the proportion is smaller, carbon is not lost in sufficient quantity, and the young plant is scarcely capable of being roused into life. These facts lead us to doubt the accuracy of those experiments which seemed to prove that germination might be accelerated, or even death arrested in seeds by excess in doses of oxygen; and it is well known that, although the name of Humboldt has been enlisted in the support of such speculations, they are by no means conformable to experience.

The consequence of the destruction of the oxygen of the air by the carbon of the seed produces a sensible heat in germination, just as a similar cause produces a like effect in flowers. Hence the heat of the masses of Barley, which are made to germinate in darkness in order to become malt. And it can scarcely be doubted that the change of the starch of that grain into sugar, is equally owing to the abstraction of a proportion of its carbon, and the addition of some other proportion of oxygen.

There can be no reasonable doubt that everything that has been created has been destined for some important purpose, and consequently one would expect that every part of a seed is important to the well-being of that seed. Nevertheless, it has been found possible to deprive an embryo of many of its parts, without actually destroying its vitality. Kidney Beans will grow pretty well with only one cotyledon, or even with neither; only in the latter case the young plant is very feeble. Oaks so treated have grown for several years, but were always remarkably small and delicate. Gourd seeds have had their radicle cut away as soon as it began to fruit, and it has been afterwards incessantly destroyed as it lengthened; the plumule also has been cut away, and yet in both cases germination has gone on as usual. Of course there must be a limit to these mutilations, but De Candolle exclaims, "Where, then, is life? Where is the seat of that mysterious principle which compels all the powers of decomposition to obey its call, to change their nature, and to become powers of recomposition?" This question is so difficult to answer, that we shall pass it by in silence.

Chapter XVI.

Of the Reproduction of Flowerless Plants.

The foregoing observations have carried us, somewhat superficially it must be confessed, but at the same time consecutively, through all the principal circumstances that occur in the life of a perfect plant.

All that relates to imperfect plants, or those which are increased by simple division of their own substance and not by seeds, is equally explicable upon the same rules, with the single exception of their reproduction. Upon this head it is necessary that we should offer a few special remarks.

It must be obvious upon consideration, that plants in which there exists neither stamens nor pistils, and in which there consequently cannot take place any of those phenomena we have lately been examining, must also be destitute of seeds; for a seed is nothing but a sac of mucous matter in a particular state of organization into which either the germ of a new individual has been conveyed, or wherein its existence has been produced by some unknown action of pollen. That Nature has not, however, neglected the means of propagating the lower tribes of plants, is plain from their great abundance in favourable situations; and, upon examination, we find that, if they have not reproductive organs like those of plants of a higher organization, they are furnished with matter of another kind which answers the purpose equally well. This matter consists of what are called *sporules* or *spores*, and is lodged in parts which may be considered analogous in their function to carpels,

although they have not only no resemblance in structure to those parts in flowering plants, but also very little among each other; the spore cases being sometimes elaborate pieces of organization, as in Ferns and Mosses, and sometimes mere simple tubes buried in the substance of the plant, as in Lichens, Fungi, &c.

In the more perfect of the tribes of flowerless plants, there can be no doubt that spores act precisely like seeds in reproducing the species; for if those from the back of the leaves of Ferns, or from the urn of a Moss are sown, as they have often been, they uniformly produce the same species as that from which they were derived. In regard to these plants, then, no difference exists between seeds and spores, except as to the origin, organization, and mode of development of the latter. Instead of having their centre divided into plumule and radicle, to which one or two cotyledons are attached, they are mere homogeneous masses of cellular substance; and instead of uniformly growing from two constant points of their surface, from one upwards, and from the other downwards, they are capable of sprouting into root or stem indifferently from any point of their surface; the nature of the part the spores produce depending not upon pre-existing organization, but upon accidental circumstances. When they begin to grow, that portion of the surface which is exposed to light extends into a stem, and that which is turned to darkness and humidity becomes root. Mirbel found in his experiments upon Marchantia, that it was possible, up to a particular period of the growth of the spores of that plant, to induce the parts they had developed to change their functions, the rudimentary stem taking on itself the office of a root, and the new-born root becoming stem when their situation was inverted.

It may be considered, then, an undoubted fact that the higher tribes of flowerless plants are multiplied by their spores, and reproduce their species each after its kind, just as much as flowering plants by their seeds. But with regard to the most simple forms of vegetation, such as Fungi, Lichens, and Sea-weeds, the subject is involved in so much greater mystery, that there are to this day Botanists of no mean reputation who believe such plants to be produced by means almost analogous to equivocal generation. In their opinion there is a common matter of vegetation, of which the green matter of Priestley may be taken as the purest form, consisting of simple globular cellules, and possessing the vital principle in each cellule. They suppose that such cellules have no specific power of reproduction, but that the various forms into which they eventually grow depend upon the atmospheric and other circumstances to which the cellules may be exposed, and not to any intrinsic property of their own. Thus such matter, which exists everywhere, if called into life upon a bare wall becomes a Lichen, in a dark cellar a Fungus, in the skin of a plant a Parasite, and in water a Conferva. It is thought that several circumstances tend to show the justice of such opinions; a Conferva, for instance, is never found in any other medium than water, and a Lichen only in air. Many forms of matter are said to be uniformly productive of the same species of plant, as, for example, decayed cheese, which has always the same kind of fungi—the Berberry, the Rose, and a host of other plants, whose parasites are always confined to particular species, and sometimes to particular organs, those of the bark not being always the same as those of the leaves. If a plant of these three tribes is examined microscopically, it will be found that it is often a mere mass of cellules, exactly like the spore or reproductive cellule, except in colour; and that, even in this respect, there is not always a difference; for in such species as the Red Snow-plant the cellules are all alike in colour as well as form. It is further asserted that the power of reproduction is not confined to the spores, but exists in all the cells of which these plants are composed; and we are told, by certain German writers, that if a Lichen be rubbed in pieces, its powder will produce a *Lichen-like* plant, although the spores are not allowed to mingle with the powder. It has been shown that one supposed species of merely cellular plants is transformed into another; and that even different genera might be seen to emanate from the very same original seed. Nees von Esenbeck watched the development of a cobwebby matter which is common in the hothouses at Bonn, and he found that when the weather was dark, as in the winter and autumn, it produced

the Sclerotium mycetospora; but that, upon the return of long, bright days, Agaricus volvaceus was born from it.

If we add to these considerations the singular fact that man holds, as it were, in his hands the power of creating these things at will, at least in the instance of the common Mushroom, which will always be produced by an artificial mixture of decayed and earthy matter, it cannot be denied that a strong *primâ facie* case is made out by those who doubt the specific power of reproduction in the spores of the lowest tribes of plants, and this without having recourse to the more questionable statements that spores become plants under one set of conditions, and animalcules under others.

It is, however, by no means clear that these arguments are well-founded. Many of them are answerable upon the ground of our imperfect powers of observation, which lead us to confound forms of matter which are essentially different. It by no means follows that spores are not differently organized from simple cells, because we cannot discover the difference in their organization. Let us remember that these parts can only be distinguished with the assistance of the finest microscopes, and we all of us know how little those instruments are capable of revealing, notwithstanding all their power. Neither have we a right to say that a cobwebby substance produces the genus Agaric in the summer, and the genus Sclerotium in the winter. We, in our blindness, may think fit to draw such distinctions; but our language ought rather to be that the Agaric and the Sclerotium are different states of the same species; for are they more different than the Pupa and the perfect Butterfly? That all sorts of errors as to the genera and species of imperfect plants do exist among Botanists is notorious. Unger has shown this to be the case in Lichens; no one can well doubt that it is so in Algæ. Unger has made it clear that not a few so-called parasitical plants are mere morbid conditions of the cuticle; and with regard to Fungi in general, what has just been said concerning their metamorphoses is quite sufficient to justify our doubts in regard to the distinctness in nature of what are called the genera and species of that tribe.

As to the conversion of living matter into either animal or vegetable forms, according to the external circumstances to which it is exposed, it must always be remembered that such supposed cases have only been found to occur when common water has been employed; and it is absurd in any observers to pretend to a knowledge of what kind of elementary matter impure water may contain. It is just as likely to contain the sperm of animalcules, invisible to our senses, as the spores of plants; and this is the more probable, when we consider that no one has ever procured either the one or the other from pure water. We have before us a jar of distilled water that has been standing freely exposed to light for eleven years, and it does not exhibit a trace of organic matter.

Surely it is more philosophical, more conformable to what we really know, to ascribe the phenomena that have lately been spoken of to myriads of microscopic spores floating in the atmosphere, and dispersed by currents of air wherever that air can penetrate; and those who are practically acquainted with the nature of spores will be the least likely to question the probability of this; for they best know how inconceivably minute, how infinitely numerous, such spores really are. Even the common observer may form some notion of the fact from the calculation that millions of millions must be contained in a single Mushroom; and that many hundreds of reproductive particles are emitted by every microscopic head of the common blue mould of cheese.

Let us not, then, be led astray by specious theories and imaginary facts concerning bodies so far beyond the cognizance of our senses; but, in the absence of demonstrative evidence to the contrary, let us believe the great Author of nature to be consistent with himself in all his works, and to have taken care to enable the most humble Seaweed to be multiplied by some means as certain and unchangeable as is provided for the most stately lord of the forest. We may rest assured, for all philosophy, and all observation, and all reason prove it, that there is no such thing in nature as blind chance; but that all things have been carefully and wisely designed with reference to the particular circumstances under which they exist.

Chapter XVII.

Of Colours.

There certainly is no point of either animal or vegetable physiology now remaining to be explained of which so little is really known as the cause of the various and varying colours with which organic matter is adorned. We see in birds the plumage marked with the strongest contrasts of the most dissimilar colours, reproduced with an exactness which is most wonderful; we find the breeders of curious races able to preserve peculiar kinds of marking, and even to improve them, with the most admirable precision; we also know that in plants, without any visible constitutional change, without accident, and without any known predisposing cause, a yellow flower will become pink, and a pink one yellow; and we know that if the portion of the stem thus altered be multiplied by the division of itself, the change is fixed and may be multiplied for ever. A dingy brownish purple tulip will suddenly, and without warning, burst forth in the most radiant beauty, its dull disagreeable colours dispersed, a pure and spotless white taking its place in part, and the brightest and deepest streaks of crimson adding richness to its purity. If we look minutely to these circumstances, we shall find that each particular cell has its own colour,—that there is no intermixture of tints, but that whatever the hues may be, each has its own cluster of cells to represent it; and even in the midst of a large mass of uniform colouring, a few cells, or even a single one, will secrete a colouring matter which forms the strongest contrast with what surrounds it; as in the Blood Red Orange, and similar cases. To what causes all these extraordinary circumstances are to be ascribed no one knows. As yet our information concerning vegetable colours is of the vaguest nature. But as it is one of very great interest, and particularly deserving the notice of the philosophical botanist, we make no scruple of borrowing from De Candolle an abstract of what is at present known or conjectured of the subject.

We are so accustomed, he remarks, to see plants decorated with the most brilliant colours, or at least invested with the green hue which characterizes every scene, that it is not without difficulty that we accustom ourselves to the idea that such colours do not exist in their primitive state, but are communicated, as it were, to vegetation by its own act; and yet this is the exact truth. The tissue of plants is in itself completely colourless, of a silvery white, or of an exceedingly pale yellow; the matters contained in the cellules are, with a few exceptions, of the same hue; but all is changed when they are once exposed to solar light.

We are accustomed to say that green plants become white in total darkness, because the phenomenon, inaccurately observed, is usually presented to us under that form: but the truth is, that although the parts of plants which originally are white or black become more or less coloured when exposed to the action of light, yet that organs, once coloured, do not in reality lose their colour when kept in darkness; if they sometimes seem to do so it is owing to this,—that if half-developed leaves are placed in the dark, they grow larger, and the green matter which coloured them, being diluted by water and spread over a greater space, appears to be paler without being itself less coloured. That the action of solar light is, in reality, the grand cause of colour in plants is proved by leaves half covered from light and half exposed, of which the latter become green and the former remains colourless; all gradations of intensity being produced in proportion to the intensity of light to which the parts are exposed.

There are plants which, in those parts which are destined to become green, have spaces that preserve their original whiteness: such plants we call variegated, and find through almost all the divisions of the vegetable kingdom. In Exogens the blotches are for the most part irregular: in Endogens they are usually arranged in bands that follow the course of the principal veins. In these places it is clear that *chromule*, or colouring matter, is either not found at all or in very small quantity, but the cause of the deficiency is entirely unknown. It is, however, interesting to remark, that variegations of this kind are best preserved in sterile, and are soonest lost in fertile soil, as if they were in reality an unhealthy state of a plant,—a supposition, however, which there are no sufficient grounds otherwise for entertaining.

We have already seen that all parts which either are green or susceptible of becoming so, decompose the carbonic acid of the sap or of the atmosphere

when they are exposed to solar light, that they part with the oxygen, and fix the carbon in their own tissue. Hence it was natural to conclude that this operation is connected with the formation of a green colour. In fact, when it takes place, greenness ensues; when it does not take place, the organ which developes in darkness, preserves the primitive white colour of the tissue; and when it has taken effect incompletely, the results are intermediate between the two preceding cases.

The deposition of carbon thus induced does not act upon the vegetable membrane; that is always of its original pearly lustre. But it forms a peculiar matter called green *chromule;* the abundance or scantiness of which is what causes the different tints of leafy surfaces. The action of the membrane produces some effect, no doubt, either by reason of its own pallid hue, or its transparency or density, or of the hairs with which it is often covered, or of the air which it contains, or, finally, of the waxy matter by which they are protected. But how does it happen that carbon, which is black, is capable of producing a green appearance in vegetation? The old physiologists supposed that it is in reality an intense blue, and not a black; and that, shining through the yellow sides of the cells, the combination of the two colours produced green. This notion, however, is disproved by the most casual inspection, for the colouring matter may be separated from the tissue with the greatest facility, and it still preserves its colour; and, besides, the yellow of tissue, if any, is so excessively feeble as to be wholly insufficient to overcome the blueness of the carbon if *it were blue.* The fact is, that the cause of carbon in the system of vegetation being green belongs to that numerous class of facts, of which no explanation can be given in the existing state of human knowledge.

Although we are justified by the mass of evidence in asserting that the green colour of plants is owing to the fixation of carbon in their tissue, in consequence of the power that light possesses of decomposing their carbonic acid, yet there are some exceptions that deserve attention. Humboldt found Poa annua and compressa, Plantago lanceolata, Trifolium arvense, Wallflower, and the Rhizomorpha verticillata green in the subterranean galleries of the mines of Freyberg, although born in total darkness, but in atmosphere highly charged either with hydrogen or nitrogen. Ferns and Mosses, again, will be green when other plants are blanched; and Humboldt found near the Canaries a Fucus which was bright grass-green, although it had grown at the depth of from 25 to 32 fathoms (190 feet.) Now, as light, according to the experiments of Bouguer, after traversing 180 feet is weakened in the proportion of 1 to 1477·8, this Fucus must have been illuminated when growing by a power 203 times less than that of a candle at a foot distance. Are we to suppose that this feeble degree of illumination was sufficient to decompose the carbonic acid of such a plant, or was not the decomposition rather owing to the operation of some unknown cause?

Leaves, which, as we very well know, are usually green, may assume different colours in special cases. It is common to see in the autumn this green change to yellow, as in the Lombardy Poplar, &c.; or to red, as in the Barberry, the Sumach, the Virginian creeper, and many kinds of Oaks. It has been ascertained by Macaire that in such cases the leaf, shortly before this change takes place, ceases to exhale oxygen in sun-light without ceasing to absorb it at night; whence he infers that the chromule is oxydized, which at first brings on a yellow and afterwards a red colour, for the most decided red always begins by a change to yellow. It is remarked that red colours are most common in leaves which contain some kind of acid, as the Vine, the Pear, the Viburnum, the Sorrel, &c. The red colouring matter obtained from leaves forms infusions which, like those from flowers, become more intense when acted upon by acids. Yellow leaves act in this manner like yellow flowers. It is supposed by some, that while red is owing to the development of acid, other colours may be ascribed to the presence of an alkali. This is however far from proved.

The same colours which mark leaves in the autumn may also be produced by certain accidents. Thus the puncture of an insect, the attacks of parasitical fungi, or injury from early frosts, produce partially or entirely yellow or red colours; and what is remarkable, the colours thus accidentally assumed are the same as the plant would have

taken of itself in the autumn: thus accidents turn the leaves of the Poplar and the Lilac yellow, of the Sumach or the Pear tree red, as they become in the autumn.

Certain leaves offer naturally on one or both their surfaces marks coloured in a particular manner, from the moment when they first unfold. Tradescantia discolor, and several Begonias have their under surface red; certain Arums are irregularly blotched with red; there are species of Amaranth which, in an apparently healthy and natural state, have leaves banded with both yellow and red. Macaire has determined that the red chromule of leaves which are thus discoloured is chemically the same as that produced in the autumn. It is worthy of note, that in regular and natural colourations red is very common, and yellow comparatively rare, although one would have thought that the latter, caused, as it seems to be, by a slighter kind of change than red, would have been the most common. Blue seems altogether excluded from changes of the leaves, except in the case of certain Eryngoes.

In many plants, the leaves which grow in the vicinity of flowers are accustomed to offer various tints, which are almost uniformly in unison with the colours of the flowers they accompany; such floral leaves or bracts are yellow in many Euphorbias, scarlet in Sages, violet in Clary, and blue in particular states of the Hydrangea. Macaire assures us that the chromule of the bracts of Salvia splendens presents the same chemical characters as that of leaves which turn red in autumn. Such bracts appear coloured because the chromule deposited in their cells varies in its degree of oxygenation, and such variations appear to be in distinct relation with the flowers. The same observations apply to many calyxes.

Why then should it be different with petals and the petal-like parts of a flower? These organs are in truth nothing but modified leaves; they are capable in particular cases, such as Hesperis Matronalis, of transforming themselves into genuine leaves, green and capable of exhaling oxygen. Can there be any the smallest reasonable doubt that these leafy petals contain in their cellules a chromule analogous to that of leaves, and consequently that when they are coloured they owe their colouring to a modification of chromule?

It is therefore probable that all the various colours of flowers, with the exception of certain special cases determined by the presence of some free alkali or acid, depend in general upon the various degrees of oxygenation of their chromule; and that this theory ought to extend to fruits and bracts where those organs participate in the same colours.

With regard to the exact relation that colours really bear to one another and to the causes that are supposed to influence them, a memoir upon the colours of flowers, published at Tubingen, in 1825, by Messrs. Schubler and Funk, is deserving of especial attention. From their account it appears that flowers may be divided into two great series—those having yellow for their type, and which are capable of passing into red or white, but never into blue; and those of which blue is the type, which can pass into red or white, but never yellow. The first of these series is called by these observers oxydized, and the second disoxydized, and they consider greenness as a state of equilibrium between the two series. De Candolle calls the first series *xanthic*, and the last *cyanic*. Upon this principle they admit the following scale, leaving white out of consideration:—

Red	Oxydized or Xanthic series.
Orange red	
Orange	
Orange yellow	
Yellow	
Yellow green	
Green	Colour of leaves.
Greenish blue	Disoxydized or Cyanic series.
Blue	
Violet blue	
Violet	
Violet red	
Red	

Which may be otherwise expressed thus—

	Green		
Cyanic or disoxydized series.	Greenish-blue	Yellow-green	Xanthic or oxydized series.
	Blue	Yellow	
	Violet-blue	Orange-yell.	
	Violet	Orange	
	Violet-red	Orange-red	
	Red		

It will be at once remarked, in considering these tables, that almost all flowers susceptible of changing colour only do it in general by rising or descending in the series to which they

belong. Thus in the xanthic series, the flowers of Marvel of Peru may be yellow, orange-yellow, or red; those of the Austrian Rose, orange yellow or orange-red; those of the Nasturtium vary from yellow to orange and orange-red; those of the garden Ranunculus pass through every gradation in the series, from red to green. As to the cyanic series, the Anemone varies from blue to violet and red, the Hyacinth from green to red through all the gradations; the Lithospermum purpuro-cœruleum from blue to violet-red; and the China-aster from violet-blue to violet, violet-red, and red.

Although there are certain exceptions to these rules, particularly in the Hyacinths, some of whose varieties approach the xanthic series, yet they are so far conformable to nature as to help us either in searching for the causes of colours, or in predicting the possible varieties of colour in flowers of the same species and sometimes of the same genus.

To the xanthic series belong all, or nearly all, the species of Cactus, Fig-Marigold, Aloe, Cytisus, Wood sorrel, Rose, Mullein, Potentilla, Œnothera, Ranunculus, Adonis, Tulip, &c.; to the cyanic series those of Campanula, Phlox, Epilobium, Hyacinth, Geranium, Anagallis, Globularia, &c. Hence we may assume that there is in general a relation between the colours of flowers and generic classification—an hypothesis which may be the more readily admitted when it is considered that some apparent exceptions to the cases just quoted in reality confirm the rule: as for instance, in the Campanula aurea, whose flowers are deep yellow, in a series otherwise cyanic: it is now known that this plant constitutes in reality a genus essentially different from Campanula, and called Musschia; and so with others.

It will have been remarked that white is omitted from these two series. It may be doubted, indeed, whether it really exists in a state of purity in flowers, and it seems to be rather some other colour reduced to an exceedingly light tint. Redouté, the French flower-painter, is said to have availed himself with great advantage of this fact. He always placed the flower he wished to represent before a sheet of paper like that on which he had made his drawing, and he uniformly found that the flower would differ from the paper in being more yellow, or more pink, or more blue, or in some other way. White Campanulas become blue when they are dried; infusions of white flowers in alcohol have always a perceptible tinge. Flowers which are white verging upon yellow, yield infusions which alkalies bring to a more decided yellow or a more positive brown; infusions of those which are white, tending to blue or red, become light red by the action of acids, and greenish by the action of alkalies.

It is probable that whiteness, or that kind of paleness which constitutes white, is owing to the chromule not being completely elaborated. This may be inferred, 1. from the analogy between this colour and blanched plants; 2. from the much greater number of white flowers in northern than in equatorial regions; and 3. from a considerable number of flowers which are born white, acquiring some other colour before they die, if exposed to solar light. Thus the Cheiranthus Chamæleo has a flower at first of a whitish colour, which afterwards becomes lemon-yellow, then red, slightly violet. Stylidium fruticosum has its young petals pale yellow, its old ones white tinged with red. The flowers of Œnothera tetraptera are at first whitish, afterwards pink, and finally red. The petals of the common Tamarind are said to be white the first day, and yellow the second. The corolla of Cobæa scandens is greenish-white the first day, and violet the next. Finally, Hibiscus mutabilis unfolds its blossoms in the morning white, by noon they are pink, and red at night. These changes are constant in the West Indies; but M. Ramon de la Sagra observed that on the 19th of October, 1828, the flowers of this plant remained white all day in the garden at the Havannah, and did not become pink till noon the next day. Now this 19th of October was remarkable for the centigrade thermometer not rising higher than 19°, while the ordinary temperature of the flowering season of the Hibiscus is 30° centigr.; so that it would seem that heat has some important connexion with the development of colour; and this notion is in accordance with the fact already mentioned, that white flowers are most common in cold countries.

Black is omitted in the two series of colours; it appears to be, in all cases, an excessively dark state of brown,

produced from a yellow base, or from a deep red; and is of too rare an occurrence to be deserving much consideration while so much remains to ascertain concerning commoner colours.

In red, there is this remarkable fact, that it belongs to both series; and if the theory of oxydation should be confirmed, it will appear to result from both the maximum and minimum of oxygenation. We may remark indeed that the various tints of red flowers differ much more from each other, than those of any other colour. Those which become red through the xanthic series have usually a more brilliant, richer, and more scarlet hue; while such as reach it through the cyanic series have a decidedly violet tinge. Rose, which is nothing but diffused red, may belong to both series; thus the rose colour of the Hydrangea evidently tends to blue, while that of the Rose itself appears to derive its origin from yellow. An infusion of red flowers in alcohol takes a tinge more or less red; add a little acid, and this colour immediately deepens; sometimes, as in the Pelargonium, it passes to orange. Alkalies produce the most variable results in different plants.

An examination of the two most irreconcileable colours, yellow and blue, points out some characters which are sufficiently well marked.

Infusions of yellow flowers in alcohol are of a clear yellow, without the flowers losing much colour. Acids produce no other effect in these infusions than to weaken their colour slightly. Alkalis make them more brilliant or browner.

Blue flowers produce, in alcohol, infusions either of a clear blue, as those of flax, or very dark, as in the case of the Aconite and the Larkspur. By the addition of acids they become red, and of alkalies green. Those which are coloured red by acids will not recover their blueness by the addition of alkalies, as sometimes happens to infusions of red flowers. Macaire having seen a red infusion of violets regain by degrees the natural blue of those flowers, by the addition of a vegetable alkali, such as quinine or strychnine, suspects that the colour of the violet depends upon the combination of their chromule with some alkali. Schubler and Funk assure us that the infusion of the Blue Day Lily (Funkia cœrulea), treated with an acid, will present in the same glass all the tints of the coloured spectrum. Blues are among the most changeable colours in vegetation, passing freely to white, and to different tints of violet and red.

From what has now been stated, it appears to result that modifications of chromule are the cause of the diversity of colours; and that these modifications depend principally upon the degree of oxygenation. In leaves fully developed the chromule is green; it gains a tendency to yellow or red when it is more oxydized, as one perceives by the changes of the colour of leaves in autumn by the effect of acids; and it appears to verge to blue when it is less oxydized, or, which comes to the same thing, more carbonated: thus we know that the flower of the Hydrangea becomes blue in a soil sufficiently impregnated with carbonate of iron.

All the brilliant spectacle of vegetable colours tends to disappear either in consequence of accidents or upon the approach of death; and what renders this subject the more curious is that, 1. discolouration is often determined by the same agents as, in other cases, produce colour; and 2. that certain organs which have no colour while alive gain when dead a very decided tint.

Solar light seems to be the most usual cause of those losses or changes of colours. While plants are alive, it acts, as we have so frequently seen, by colouring them; but in certain cases its too powerful action discolours them. Thus the cultivators of Tulips place their flowers under a tent, knowing very well that the direct action of the sun tends to alter their colours more promptly than would be the case in the shade. A great number of delicate flowers, particularly of those belonging to the cyanic series, exhibit this phenomenon.

Most aquatic plants gain in death a whitish hue; this is particularly remarked in Sea-weeds, which, from the most brilliant blue or green, pass to white when they die, an effect which seems to be augmented when they are exposed to air and light; but the exact mode of action of these several agents has not been appreciated. Fresh-water confervæ and several aquatic herbs present the same system of discoloration. Air evidently produces its effect by altering their chromule, probably by abstracting its carbon;

for such is the ordinary effect of the air upon dead vegetable matter. Charas, in particular, when dried in the air become quite white; this tint is no doubt to be ascribed to the alteration of their chromule, but in all probability also to the enormous quantity of calcareous matter that those plants, while alive, fix in their tissue; other cases of a like nature may be easily named. The straw-coloured hue of the green parts in a great number of dead vegetables after death depends, on the one hand, upon the oxygenation of their chromule, and on the other on the decarbonization determined after death by the action of the oxygen of the air.

Most leaves when they die are invested with a uniform russet colour; it has some analogy with what happens in bletted fruits, such as the Medlar. Such a state of the leaf may very well be owing in leaves, as well as in fruits, to an alteration in their principles analogous to putrefaction or fermentation. It is always accompanied with a great loss of water; but we have no direct evidence as to the nature of this change.

Chapter XVIII.

Of Odours.

Not less curious nor less difficult to reduce to any intelligible laws is the subject of Vegetable Odours. Our senses are daily gratified by the sweet perfumes exhaled by the leaves and flowers that surround us; and art exhausts its skill to preserve them by means which enable us always to have them present for our use; but as to the reasons why one kind of flower is odoriferous, and another scentless, we are still more in the dark than in what relates to colour. Here, therefore, we shall confine ourselves very much to a mere statement of facts, introducing theory only in cases which may appear to be pretty well understood. For this purpose we again avail ourselves of many of the materials collected by De Candolle in his invaluable *Vegetable Physiology.*

All odours are owing to the disengagement of volatile matter, and as there are few organized bodies in which, in their natural state, there is not some volatile constituent part, so neither are there many organic bodies absolutely destitute of smell. But it is only to cases in which the scent is very perceptible to our senses that we apply the idea of odoriferous, and it is consequently to those that we here confine ourselves; dividing them into *permanent*, *fugitive*, and *intermittent.*

Those odours are the most *permanent* in which the volatile matter is so inclosed in cells and concentrated as to disperse slowly. Of this many instances are afforded by wood and bark, which being in truth the only permanent parts of vegetation, will of necessity be the receptacle of durable odours; such parts are not scented, because of their own proper nature, for all the tissue of plants is originally scentless, or nearly so, but they owe their property to the fragrant secretions imprisoned in their cavities, and the permanence of their odour will be proportioned to the difficulty the volatile parts of their secretions experience in escaping through the tissue which incloses them, as well as to the degree in which the volatile matter may be fixed. Thus resinous woods, such as Cedar and Cypress, are fragrant for an indefinite period, because the resinous matter in which their odour resides is parted with slowly. Parts, whose scent resides in essential oil, preserve their scent for a long time, where the essential oil is but slightly volatile, or the wood is thick and hard: thus the Rose-wood of Teneriffe (not the Rose-wood of the English cabinet-makers), produced by Convolvulus scoparius, preserves its odour a very long time; and in order to elicit it, it is necessary to rub the wood strongly, so as to produce heat enough to volatilize the matter which is locked up in the very compact tissue of which that plant consists. The necessity of producing a little heat, in order to produce an exhalation of the volatile matter, is further exemplified by the fragrance emitted by many woods, otherwise scentless, when exposed to the violent friction of a turner's lathe: Beech is said to acquire, under such circumstances, the smell of Roses. But when, on the other hand, the volatile matter is inclosed in wood of a loose texture, neither is heat required to elicit it, nor has the wood, if exposed to the air, the power of retaining it for any considerable time, for the oxygen of the atmosphere will seize upon it rapidly, and quickly leave nothing behind but the inodorous tissue: this happens to Cassia and Cinnamon.

Fugitive smells are those which, belonging to perishable organs, are either

extremely perishable in their very nature, or are placed in tissue of the laxest kind, or are situated on the surface of plants where their volatile parts are continually abstracted by the atmosphere, or finally are secreted in quantities so small that a short exposure to air suffices to dissipate them. All these odours are produced only during the life of a plant; they are dispersed as they are formed, and after death leave no trace of their existence behind them. Like permanent odours these are continually given off, and in some plants, as the Orange and the Violet, without any variation in intensity in different states of the atmosphere; but in the majority of cases the power of the smell will vary according to the elevation of temperature, and the dampness of the air. This fact must be familiar to all who are acquainted with gardens. In the hot, dry weather of a summer's noon, flowers either become scentless, or at least lose a large proportion of their usual fragrance; and in walking through a wilderness of the most sweet-smelling plants, we find little sign of their odour, unless they are bruised or trampled upon. But if a heavy shower should come on, all will be changed in an hour's time; every leaf, every flower, will emit its peculiar odour; the Musk plant (Mimulus moschatus) will fill the air with its singular scent, and it will be obvious that the addition of moisture to the air has produced a total change in the action of the odoriferous organs of plants.

The same phenomenon is daily repeated in the driest days of autumn. Those only who are accustomed to take their early walks abroad can have any idea of the difference between a richly-stored garden early in the morning and at noon. When the sun has dried the air, and has been beating for some time upon vegetation, ill able to bear his action in consequence of the dryness of the source from which they draw their means of compensating for evaporation, however beautiful a garden may still remain, it cannot be compared to the same place before the dew has dispersed—when every herb, tree, and flower is pouring forth a stream of the most varied and delicious fragrance—when the air is impregnated with the most delicate balsamic odours—and when all nature seems as if offering up incense in gratitude for the refreshing powers of darkness and of dew. Let any one, for example, visit a thicket of Cistuses at noon, and again the next morning, and the difference will be exceedingly apparent. To what cause this is owing is unknown; possibly the effect of dryness and excessive heat may be to close the stomates, and to contract the tissue of plants, thus rendering it difficult for volatile matter to pass through their cuticle: it may also act by depriving them of the necessary proportion of water required to enable them to perform their functions of secretion and assimilation, and thus arrest for a time the elaboration of the fugitive principles upon which fragrance depends. While, however, dew and showers, with intervals of bright light, are eminently favourable to the eliciting of vegetable perfumes, a continuance of wet and gloomy weather, without much sunshine, is as greatly unfavourable. This latter circumstance is explicable upon the general law of physiology, that secretions cannot be readily produced without the direct assistance of the sun's light.

With regard to what we call *intermittent* odours, no explanation seems possible in the present state of our knowledge. A few examples of them will therefore be all that we can give. All dingy-flowered plants, such as botanists call *tristes*, belong to this class; such as the Pelargonium triste, Hesperis tristis, Gladiolus tristis, which are almost entirely scentless during the day, but become deliciously fragrant at night. Great numbers of Orchideous plants have flowers possessing the same property; the Catasetums have a fine aromatic odour at night, none in the day, except C. purum; Cymbidium Sinense is also chiefly fragrant at night; and so with a great many more. Cestrum nocturnum is another plant of the same nature; in the day it has no odour, at night its perfume is extremely powerful. One of the most singular instances of exceptions to all rules appears to be referable to this class: Cacalia septentrionalis exhales an aromatic odour if exposed to the direct rays of the sun, and if anything is interposed between it and the sun its odour disappears, but is renewed as soon as the interference is removed.

Agreeable as vegetable odours usually are to our senses, there are some striking exceptions. Many Stapelias, the Arum dracunculus, and several other species of the same genus, whose

flowers are of a deep livid colour, have a smell so completely that of putrid meat, that flies actually deposit their eggs in them by mistake ; Arum trifidum has an abominable stercoraceous odour ; and the pollen of the Sweet Chestnut and the Barberry has a peculiarly disagreeable smell. Even the most delicate kinds of fragrance when concentrated prove disagreeable, and in many cases, in their simple state, act powerfully upon the nerves ; even oil of Roses highly concentrated can scarcely be supported, and every one knows that a perfumer's shop, although the receptacle of the sweetest essences, is by no means an agreeable place. The spasmodic affections produced by the odours of flowers are more common than is generally supposed, but vary in different individuals according to their respective powers of endurance. Some of the most remarkable cases are the following :—The Jonquil and the Tuberose are insupportable by persons of delicate nerves ; few can bear the fragrance of the Lilac, especially in a room ; even Violets, the last flowers to be suspected, have in many cases proved deleterious ; De Candolle says he has witnessed many ladies faint from carrying too many of them on their persons, or from having placed them too near them when asleep. It is asserted that people have died from being shut up in a room in which the Oleander was in flower ; hysterics have been brought on by the Musk Mallow ; Saffron has been known to produce swooning ; and the flowers of Lobelia longiflora have caused suffocation. The odours of other organs may also produce inconvenient consequences : the Elder, the Walnut, and the Anagyris bring on headache in persons who sleep beneath their shade ; and the Manchineel tree is said to have proved fatal to travellers who have trusted to its shelter.

Vague and unsatisfactory as all these details must be admitted to be, they are so connected with one of the most curious inquiries in either the vegetable or animal kingdom, that we think we cannot have done otherwise than render good service to our readers by letting them form a part of this treatise, especially as they are scarcely to be found adverted to in our English elementary works ; and we close what relates to the physiology of plants, by strongly recommending the investigation of the subject to all those whose tastes, leisure, and attainments may lead them to occupy themselves with one of the richest fields of inquiry which yet remain in Nature to be explored.

Part III.*—Systematic Botany.

Chapter I.

Of the General Nature of the Plan that is followed in classifying Objects.

When an observer first sets himself to examine the various plants with which the earth is clothed, he finds his attention forcibly arrested by their great diversity of structure, and by the seemingly endless variations under which nature presents herself in a vegetable form. The first meadow that he enters will bring before him a crowd of individuals, which, although at first sight all so similar that they might be looked upon as one large assemblage of the same form of vegetable matter, yet, upon a more exact inspection, prove to consist of endless variations of structure: some will be found to have netted, others striated leaves; some to bear their heads erect in the form of green scaly cones, while others bring forth gaily coloured cups, and another set, without either cones or cups, creep along the ground, and seem as it were to form a carpet for the floor of that vast enclosure in which so many millions of vegetable beings are assembled. Upon a yet nearer inspection, it is found that this mass of individuals, confused as it seems, may be abstracted into groups that agree with each other in every petty detail of structure; and that the scene consists of nothing but such groups excessively intermixed; these groups are *Species*. As soon as the mind has thus assorted the species, it becomes evident that there are groups among them also, having certain other attributes in common by which they differ from one another; these are again mentally assorted, and form abstractions of a higher order called *Genera*. If the field is extensive enough, genera will themselves next be put into groups distinguished in the mind of the observer by some other qualities that they possess in common, and *Orders* are the result. And thus, by a series of abstractions of different degrees, in each of which the "distinguishing peculiarities are lost sight of, and attention is limited to those attributes which belong to the individuals in common," a classification of some kind or other is arrived at. If, in such a supposed case, the observer should judge among the individuals correctly of all the points of agreement or disagreement that really exist between them, and should have placed them in his mind near or distant according to the nearness of their agreement, or the greatness of the sum of their differences, he will have formed a *natural* classification; that is to say, a classification in which those individuals will stand nearest each other that are most alike, and those be stationed farthest apart which are least alike. If, on the other hand, he should have erred in this respect, and have abstracted the individuals according to certain single characters, and not according to the sum of them, he would have formed an *artificial* classification.

But as, in either case, he would, in the first instance, have abstracted the individuals according to what would have appeared to him their identity, and so assorted the whole into species, and as he could hardly commit any considerable errors in that respect, seeing that no great doubt would be likely to arise as to what constitutes identity, it would follow that species would form the basis of his classification, whether natural or artificial.

This is precisely the course that is taken by Botanists in assorting the vast mass of individuals with which the face of the earth is beautified; they first combine the individuals into species, next arrange the species in genera, then collect the genera into orders; and thus, by successively losing sight of differences, and confining their attention to points of agreement, they finally reduce the whole to a regular classification.

It is obvious, however, that this kind of progress must be arbitrary and uncertain in the highest degree, unless some rules are laid down for determining what is to be considered the relative value of the differences that must be employed in classification; and such a necessity has given rise to that department of the science on which we are now to treat, in which undoubtedly there is, from the very nature of the subject, much that is vague, but in which there also is much that is well deserving the attention of the philosopher.

Under any circumstances it is desirable, that in instituting an inquiry to be conducted by numerous independent observers, certain rules should be agreed upon, and certain prin-

* Descriptive Botany, which it was originally intended should form the third part of this Treatise, will occupy the fourth part.

ciples settled as the basis of their investigation, otherwise, however limited the field of observation may be, there is a danger of the results being attended by such discrepancies as will vitiate and render useless all the labour that may be expended. That it is more especially important for this to be done in Botany, is manifest, if we consider how very numerous are the species that constitute this vast section of the animated world; how endless are the varieties of their structure; how liable they are, from their very nature, to shift and change their appearance, according as they are influenced by this or that combination of external influences.

What number of species of plants may really exist upon the earth will possibly never be known. At present there is no means of forming even an approximative estimate, so little has been effected in the examination of a large portion of the globe, and so imperfectly are we acquainted with the results of the examination that has been hitherto made.

Professor Lindley estimated them in 1835 at about 86,000, but this is probably much too low, and it seems that we should be justified in carrying the number up to 100,000. Meyen raises the number to 200,000 (*Pflanzen Geographie*, p. 5).

Chapter II.

Of Species and Varieties.

According to Jussieu and others, a species is a combination of individuals alike (*semblables*) in all their parts. De Candolle makes it "a collection of all the individuals which resemble each other more than they resemble anything else; which can by mutual fecundation produce fertile individuals; and which re-produce themselves, by generation, in such a manner that we may from analogy suppose them all sprung originally from one single individual." "The first unity after individuality;"—"a systematic combination of homogeneous individuals;"—"a collection of individuals which will breed together, and produce fertile offspring," are other definitions. In order to understand these rightly, and to see how they apply, it is necessary to separate the definitions into two parts, the one comprehending the structural, the other the physiological characters assigned to a species.

So far as these definitions depend upon structure, they seem to amount to this, that all individuals which are identical, constitute in the aggregate a species. It is therefore necessary to inquire what is here meant by the term "identity." It is manifest that it is not employed in its strictest sense; for there probably never was even one pair of plants of the very same size, form, or colour, in all respects: the word must therefore be taken to bear a more extensive application.

All plants are considered botanically identical in which the structure *nearly* corresponds. For example, if one individual has leaves two inches long, and another, those parts three inches long, the two would, nevertheless, be considered identical, provided they corresponded in all other respects; nor is it here that the identity contemplated in the previous definitions can be said to stop. If one plant has white flowers and pale green leaves, while another has blue flowers and dark green leaves, but are otherwise the same, they would still be considered identical: or the word may be applied yet more widely; for suppose one fruit-tree bore small round sweet apples, red flowers, and shining leaves, and another bore large angular acid apples, white flowers, and opaque leaves, nevertheless, and notwithstanding these differences, the two would come within the idea of identity, provided their differences went no farther. The reason of such a latitude being given to the application of the term is, that in plants many external characters are of a fleeting and transitory nature, as is known by experience, and such transitory characters are not taken into account in comparing two individuals. Of that nature are, in general, colour, taste, size, and, sometimes, even form. The seed of a plant with white flowers may produce an individual with blue ones; or the seed of an acid fruit may give birth to a plant bearing sweet fruit. These are facts ascertained by experience, and therefore all such peculiarities are in general estimated as unimportant in determining the collection of individuals into species.

Botanical identity must hence be understood as meaning a correspondence in all *permanent* characters. The application of this rule depends entirely upon the knowledge and judgment of the botanist, and is unfortunately liable to much uncertainty, from a variety of causes, depending upon the specific

peculiarities of different plants. What is permanent in one species is transitory in another; and what is transitory in one is permanent in another, for no known cause. For example, the colour of the flowers is liable to variation, and consequently unimportant in Campanula, Pyrus, Hyacinthus, and others; but it appears permanent in the genus Mesembryanthemum. The presence or absence of hairs is of no permanency in Rosa, Pyrus, Rubus, &c., and yet it is generally found a distinction of value in other plants. The form of the fruit is notoriously variable in Pyrus, Cucumis, Prunus, and others; but in Carex, Mitrasacme, &c. it is found constant. The leaves too, which in their form are uncertain in Eucalyptus, Dahlia, Pyrus, and some few genera, often afford excellent discriminative marks. For these reasons it is perhaps impossible to decide with certainty what is a species upon structural differences alone.

The physiological definition of a species is, that all the individuals that belong to it will breed together and produce successors having the same power of reproduction by seed. This idea has evidently been derived from the animal kingdom, in which, among the higher orders of animals at least, it seems liable to no exception. In plants it is exposed to two objections; firstly, it is inapplicable to by far the largest part of the vegetable kingdom, for we possess no means of ascertaining whether species will breed together or not, except in the case of the few that are immediately within our reach in a wild or cultivated state; and secondly, it implies that no individuals will so breed together, except those which belong to the same species, a statement of which we possess no means of ascertaining the truth, and which seems opposed to experiment. It would hardly be doubted, that the wild wood Strawberry of Europe is distinct as a species from the American kind, *Fragaria Virginiana*, for they are different in their foliage, in their flowers, in their fruit, and in all their habits, yet they certainly will breed together and produce fertile offspring; and numerous similar cases of Pelargonia, Gladioli, &c., are upon record. It may, however, be alleged that all the well ascertained cases of this kind are really instances of the intermixture of strongly marked varieties of the same species; that the wild wood Strawberry of Europe is not more different from the American than a Shetland pony from an Arabian horse; and that moreover, as it is certain that the definition applies to many species that are distinct beyond all dispute, as the Apple and the Pear, the Gooseberry and the Currant, it is probable that it applies in other cases as well.

Be this as it may, it is at least certain that the physiological definition of a species is merely theoretical, and that the only one which is applicable to practical purposes is that which is derived from organic identity, as above explained. But it has already been shown, that it is impossible to determine what is a species upon structural differences alone, and hence it may seem impossible to decide the question by any certain rule whatever. And that is the truth; let botanists explain, and define and refine as much as they will, they are driven at last to admit that whatever theoretical limits may be assigned to a species, there are none of a positive kind; but that the determination of the point must after all be left to the experience and judgment of the observer.

The rules that are to be attended to in forming a judgment in this matter may be stated thus: species are not usually distinguished by differences in the internal organization of individuals, or in the plan upon which their external parts are combined,—those circumstances are not taken into account till genera and the higher assortments of species come to be formed; but upon differences of a superficial and external kind, or such as are independent of internal organization.

The cause of the same species varying in regard to such points as these has been well stated by De Candolle. "Let us suppose, what really happens, that the seeds of plants are scattered at hazard over the surface of the earth, or, to speak more correctly, by causes that have no necessary connexion with the existence of those plants; such seeds will find themselves in an infinite variety of situations; some which have fallen in soil that is too tenacious or too loose, too dry or too wet, too hot or too cold, do not grow and are soon destroyed. But between these extremes, some will succeed, although it may be under very different circumstances. Thus, for instance, if the place is not light enough, the plant will be half blanched, as will be indicated by its

paleness and feebleness, or by being spotted, or by the diminution or even loss of its hairs; if the light is too bright the plant will be stronger, dwarfer, more deeply coloured, harder, and more velvety than usual. Temperature also exercises some influence, though in a less degree; in a cold climate the same plants are smaller and weaker than ordinary; the colour of the flowers and fruits is paler, the wood worse ripened, their leaves more deciduous, their fruit often abortive, and the sap destined to nourish it, throwing itself into the neighbouring parts, sometimes changes their appearance. In a hot climate plants become larger, produce more wood, and their leaves have brighter colours, and a higher flavour. In the same climate humidity causes the appearance of differences without end; plants that grow in water lose all their hairs, their leaves become divided into capillary segments so as to look like hairy roots; their stems and flower stalks lengthen to reach the surface of the water; and these different effects are still further variable as the water is still or agitated, clear or turbid, pure or mixed with heterogeneous substances; the varieties of *Ranunculus aquatilis* offer a remarkable example of this. If, on the other hand, a plant accustomed to water is found to live in a drier soil, it becomes covered with hairs, remains smaller than usual, and acquires greater hardness. In air rarified like that of mountains, plants are generally found smaller and more stunted than usual, while their flowers are larger than upon the plains. The influence of soil is not less manifest; if it is tenacious, the roots, which penetrate it with difficulty, remain small, hard, and clustered; if it is very sandy, the roots become large, fleshy, and fully formed; if it contains a great quantity of carbon, the colours of the flower are often altered, as those of the Hydrangea into blue, and of the Pink into violet; if it is charged with salt, or if the plant is within the reach of salt, even brought through the atmosphere, we usually find the leaves more fleshy and more glaucous, as in *Lotus corniculatus*. All these different circumstances, combined with each other in nature, are fertile causes of varieties, which are still further multiplied by cultivation."

To these causes of variation has to be added an inherent tendency in certain species to throw off one peculiarity, and to assume another as often as they are propagated by seed. Experience is the only guide to the discovery of such variations, and herein much of the advantage of a practised over an unpractised botanist consists; for the latter knows that certain peculiarities are not permanent, not as a point of theory, but as a matter of fact, independent of all theory. He knows, for instance, that if the seeds of the *Anemone coronaria* with white flowers are sown, they will produce individuals with flowers of many other colours; that if Purple Beech seeds are sown, they will form plants with green, pale purple, and deep purple leaves; or that whenever a bed of seedling plants of any long cultivated species is examined, a number of discrepancies will occur among them, either in their flowers or their leaves, or some other part.

The particulars upon which species are usually distinguished are:—1. *Duration;* 2. *Dimension;* 3. *Surface;* 4. *Form;* 5. *Division;* 6. *Numerical Proportion;* 7. *Colour.* We will consider the value of each of these separately.

Duration comprehends three spaces of time only, namely duration for a period defined by the production of flowers and fruit, after which the individual perishes: these are annuals; duration of the roots for an indefinite period, the stems flowering and fruiting, and perishing annually: these are perennials or herbaceous plants; and duration of both roots and stems for an indefinite period, the latter not perishing after the maturation of the fruit, but becoming woody and giving birth to new stems (branches): these are shrubs and trees. It may be taken as an universal rule, that individuals differing in points of this kind are specifically distinct. It is not indeed probable, that differences of so important a kind as these, which are inherent in the very nature of the individuals, and which could not be altered without an alteration in their whole physiological condition, should be of a transitory kind; it is almost certain that the very few cases in books where a plant is said to be annual in one of its varieties and perennial in another, are mere instances of botanical errors. There is no proof to the contrary of this in the common Mignonette, which is annual in England, and a kind of undershrub on the coast of the Mediterranean, nor in other such cases; for the Mignonette and

plants of a similar kind are not in reality, when in our gardens, at all different constitutionally from the wild species, but they are incapable of enduring the cold and wet of winter; and hence, as they produce their flowers and fruit in a few months, they are only treated as annuals in such countries as England; if they are kept in a greenhouse they preserve all their native habits unaltered, and become small undershrubs.

Dimension is rarely of importance even in extreme cases; a plant only a few inches high in a poor dry soil may become very much larger in a damp rich soil; the effect of cultivation is to increase the dimensions of plants in all their parts, or sometimes even to diminish them, as is the case in the numerous dwarf varieties of common species, found in every garden. We have Dahlias reduced in stature by dwarfing from six feet to two feet; *Dianthus barbatus* from eighteen inches to three inches, and even Spruce Firs, in the case of the Clanbrasil Fir, reduced from timber trees to a pigmy bush. And a similar result occurs from climate: it is well known that many of the trees of plains become more and more dwarf as they ascend mountains, till at length they become mere underwood, and the same thing is true of herbaceous plants and annuals. It sometimes, however, happens that differences, not in general dimensions, but in those of particular parts, become of specific importance, as, for example, in the case of two individuals resembling each other in most respects and growing in different soils, of which that growing in damp rich soil bears small flowers, and the other in dry sterile soil bears large flowers. Distinctions of even this sort are, however, to be distrusted under any circumstances; for the usual size of flowers may either be increased by a portion of them being destroyed when the nutriment intended for many is directed to the support of one, or diminished by the production of many more flowers than usual, when each flower has but a sparing supply of food.

The *surface* of individuals is sometimes remarkably dissimilar, the difference arising from several distinct causes, of unequal value in judging of identity. Surface is sometimes what is technically called rugose, in consequence of the parenchyma between veins being convex. This is an invariable character if contrasted with smoothness,—that is, a flatness of the parenchyma; but it is apt to run into a greater degree of convexity when leaves become *crisp*, or *bullate*. It will be found, upon examination, that all such leaves are variations of a rugose surface; *Mentha crispa*, for example. In like manner, if an individual is marked by having its veins projecting above the parenchyma, it is never referable to a species whose veins are level with the parenchyma. Some plants have their surface so smooth as to seem polished: this is a constant character; and of the same value is the presence of asperities in the form of tubercles, or hard-based hairs, originating below the parenchyma. These, as well as glandular hairs, secreting something at their points, are indications of constitutional peculiarities, which the species never loses or alters, under whatever circumstances it may be placed. Thus, in the difficult genera, Rosa and Rubus, those individuals in which secreting or glandular hairs exist, are apparently referable to species essentially distinct from those in which no such hairs exist. Far otherwise is it with common lymphatic hairs, which, as has already been shown, may appear in greater or less abundance upon the very same individual, according to the different circumstances in which it is placed.

In the common Dog Rose (*R. canina*) we have leaves entirely destitute of hairs; other individuals with a few hairs on the midrib; others with them spread over the whole lower surface; then again they overrun the upper surface, and thus produce diversities of appearance which have led to the creation of many spurious species. It may be considered a certain rule, that in all cases differences in the degree of hairiness of individuals are unimportant if unaccompanied by further differences in other respects; nevertheless, the terms denoting the presence, or absence, or quantity of lymphatic hairs, are in constant use among the best systematists; because, as the appearances produced by them are of a very obvious kind, they are convenient indications of distinction when combined with other circumstances. These observations apply chiefly to leaves; hairiness of the stem is far more constant; and where hairs of any kind appear upon parts that are usually destitute of them, as, for instance, the co-

rolla, the stamens, or the ovary, such circumstances are usually a permanent indication of species. It has also been thought that the direction in which lymphatic hairs point, may be taken as a good specific character; and this has been applied to the genera *Myosotis* and others, but it is doubtful whether this is right*. The presence or absence of prickles, which are a form of hairs, is apparently of certain value in extreme cases, or in comparing wild plants with each other; but its value is much diminished when wild and cultivated individuals are objects of comparison; for it not unfrequently occurs that prickly species become unarmed when introduced into gardens, as has happened to Rosa alba, in a very prickly genus. The surface of a plant is sometimes covered with a slight waxy glaucous secretion constituting *bloom*. A good deal of value is attached by Botanists to this mark when it appears, and it often proves of much use in determining doubtful points; as, for example, in defining the limits between *Aster cyaneus* and *A. rubricaulis*.

The *form* of different parts is often one of the most delusive characters, although in many cases it seems to be of value. De Candolle well observes, that as to the general forms of organs, "they are only of importance as they are the consequence of anatomical differences; that is to say, of the arrangement of the veins. The form of a leaf may vary within tolerably wide limits, without any material change in the arrangement of its veins." In fact, nothing is more common than striking differences in the form of the foliaceous organs in the same species. The gardens are filled with narrow-leaved, broad-leaved, long-leaved varieties, well known to have been raised from the seed of species in which the leaves are altogether different. The entire-leaved Ash, a most remarkable tree, is a striking instance of this. Its leaves are ovate, and simply serrated. The common Ash has pinnated leaves, and yet there seems no doubt that the seeds of the entire-leaved Ash will produce the common pinnated state of the species, and that consequently the former is a mere accidental variety of the latter. In general, however, differences in the form of the organs of fructification, provided they are well marked, are constant, except in the case of succulent fruits, the form of which is very changeable and uncertain.

* De Candolle states that the form of hairs is in general very constant in a species, but it forms a character that is hardly ever attendedt

Characters, derived from differences in the degree of *division* of organs, are to be distinguished into two classes: 1. those which depend upon mere lacerations of the parenchyma of the same organ; and 2. those which arise from the non-adherence of contiguous organs. To the first class belong all toothings, or lacerations of the margin of leaves, petals, &c.; and these, in the leaf at least, are seldom of any consequence, provided they are merely different in degree. For instance, the common Alder (*Alnus glutinosa*) usually has leaves with a mere serrated margin, but sometimes they are pinnatifid, or almost pinnated; and this is a common circumstance. Hence, the numbers of cut-leaved, fern-leaved, and similar varieties of plants, common in gardens. It is less usual for leaves which are quite entire to separate into divisions, but even this occurs in the *Symphoria racemosa*, the young vigorous shoots of which are sometimes covered with deeply sinuated leaves, while those of the remainder of the bush have not a trace of division. Lacerations of the margin of petals are usually constant, as between fringed and fringeless cases; but if there is any laceration at all, mere differences in degree are to be distrusted. The second class of differences includes all the modifications of division observable in the calyx, or corolla, &c., and generally these are very uniform in all individuals of the same species.

Numerical proportion has been well disposed of by one of the most learned of modern botanical writers. "Differences," says De Candolle, "in the number of parts demand the most serious attention on the part of the naturalist, either because their importance has been often exaggerated, or because this importance is sometimes very great, and sometimes very small. In the midst of such anomalies, let us attempt to reduce it to its just value. General differences in the number of stems, branches, leaves, or flowers, have scarcely ever any importance, unless in extreme cases, or as between unity and some high number, or when special observation has shown that certain numbers are constant. Thus the number of leaves or flowers in a whorl may vary by 1, 2, or 3 above or below the

customary number; but the greater the difference becomes, the more attention must be paid not to confound different things. On the other hand, there are certain plants in which certain numbers appear constant; thus *Convallaria bifolia* has constantly two leaves, *Trillium sessile*, three, *Paris quadrifolia*, almost always four, &c.; *Tulipa Gesneriana* bears but one flower on a stalk, *Lonicera Xylosteum* always two; *Cytisus triflorus* usually three, *Litsea tetranthus* four, and so on. With respect to this, we ought to take as a general rule, in objects of number in Botany, that *the number of organs or of parts is most subject to variation, the greater it is.* Although we know of many exceptions to this rule, it is nevertheless sufficiently constant to serve as a guide in practice. The absolute number of the parts of flowers and fruits comes within the preceding observations, but nevertheless deserves more confidence than that of other organs; it is rare for differences in these parts to exceed one *plus* or *minus*, and therefore care should be taken to determine their number with precision. We must moreover be on our guard against natural adhesions and accidental abortions, which in certain cases may mask the real number. But number becomes a character of high importance, when such changes, instead of being absolute, are relative; that a plant with four petals and four stamens should take five petals and five stamens, is common enough in the same species; but if, preserving the four petals, it should change the number of stamens, we then obtain an important character, provided always that we are not deceived by accidental adhesions and abortions."

With regard to *Colour*, it is probably of all the differences by which individuals are distinguished from each other, the least important; and as a general rule it is to be left out of consideration. Nevertheless there is one point of view under which it becomes a less fallacious guide. From some unknown cause, the tendency of particular colours is to change in certain directions, but not in others; as for example, blue into red or white, but not into yellow; and yellow into green or scarlet, or brown, but not into blue. (See page 122, &c.) When therefore we have to compare two individuals, much alike in other respects, but the one with yellow flowers and the other with blue, the probability is that they are two distinct species. There are moreover certain genera in which colour seems fixed in particular species, as in Mesembryanthemum, and Aconitum.

Odour, *taste*, and similar qualities, are by themselves of no moment whatever; they are owing much more to the peculiar circumstances under which a plant may be placed while growing, than to any specific property. For instance, aromatic plants become more aromatic as they are exposed to the powerful action of bright light in dry places, and less so, as the situation in which they grow is shaded; an acid fruit on a north wall becomes a sweet fruit on a southern exposure; celery growing in ditches developes its dangerous extractive principle, and becomes deleterious; but in a dry garden it is incapable of developing it, and becomes an agreeable salad.

These statements are purposely confined to points upon which there can be no difference of opinion, and they serve to show in a striking light, the excessive absurdity of species-mongers, who constitute a species out of every trifling variety in the surface, form, dimensions, or divisions of the organs of plants; and who, by such a proceeding, not only embarrass science with numberless names, but introduce the greatest confusion into the distinctions of genuine species. We will quote a few striking examples of this practice. The genus Salix is fixed by Mr. Borrer at 71 British species; Koch and Lindley have reduced them to 29; Rubus is reported to have 21 British species; it can hardly be doubted that they are all reducible to 8, if not to 6 genuine species. The number of Austrian Menthas is raised to 44 by Host: Mr. Bentham has shown that they ought to be diminished to 10. Rosa was stated by Mr. Wood to comprehend 22 species, mostly distinguished by the single or double serrations of their leaves, the density of their prickles, the surface of their fruit, the hairiness of the leaves; of these 14 only at the utmost can be allowed as genuine. It is inconceivable to what an extent this evil of multiplying species upon insufficient characters has in modern times been carried, especially among the third-rate Botanists of Germany. *Veronica*, *Viola*, *Salvia*, *Scabiosa*, and almost all large genera, have passed through their hands, and now require to be again ex-

amined by some Botanist of sound judgment and sane mind, in order to be restored to an intelligible state. There is at this moment in a Botanic garden near London a collection of Rhubarbs divided by a worthy Spanish Botanist into fifty or sixty species; and yet there is no evidence to show that the gardens really contain, at the outside, above six or seven genuine species. This is mere childishness, or scientific fatuity.

No plant can be considered a species that is not capable of being characterized by *several clear, permanent, well-defined marks*, by which it will be distinguished from all its neighbouring species; it can very rarely happen that one single character is all that exists as a difference between two species. To say that this plant differs from that in having its leaves rather more cordate at the base, or slightly hairy underneath, or linear-lanceolate instead of oval, or its branches many-flowered instead of few-flowered, and so on, is merely to point out the existence of certain differences, and by no means to show that such marks belong to specific distinctions. Theodore Helm, who is supposed to be the expositor of the systematic views of Professor Mohs, the celebrated mineralogist, has made some good observations upon this point. "If I have two straws before me, of which one is six inches long and the other seven, I can distinguish them perfectly by that circumstance; and two plants otherwise alike, one with six and the other with seven flowers, may be well and certainly distinguished by those marks of number only, and so on. *But let me ask, are these natural-history differences? (differentiæ physico-historicæ); are they not altogether distinct from the principles of natural-history: and do not they obviously come within the idea of systematic identity?* (*homogeneitas.*)" It is greatly to be regretted, that we should so often find length, and breadth, and size, and the like, referred to in the works of men of *Science* (?), as affording characteristic distinctions; it is still more to be regretted, that the length, breadth, and so on of all these parts, should be most minutely and carefully reduced to inches and lines; and it is perfectly lamentable to find upon record distinctions such as these. "This *Sisyrinchium*, formerly confounded with *S. anceps*, certainly differs from it in having its spathes *more* short than the flowers, its stem *less* compressed, its leaves *more* wide, its flowers *more* large, and mixed with blue and yellow; finally it is a *native of a different country*, and cannot pass the winter *out of a greenhouse*, while *S. anceps* lives all the year long in the open ground. *Eucomis punctata* resembles *Eucomis regia* very much, but it differs principally in its leaves being long*er*, narrow*er*, and *more* pointed, in its scape being high*er*, and its spike twice or thrice *as long*, and terminated by *much shorter* leaves."

One fertile cause of the perplexity that has been introduced into specific distinctions, has been the artificial creation of *hybrid plants* in gardens, and their natural production among wild plants. The former is a notorious occurrence; the latter has been denied altogether; or admitted in a few special cases, such as certain Gentians, Saxifrages, &c.; but is probably a very common circumstance. It has been argued that as mules are almost unknown among animals in a state of nature, they should be equally rare among plants; and that in both kingdoms they only occur among species in a state of artificial life, resulting from domestication. But it seems to us that this matter has not been well considered. If mules are rare in wild animals, that circumstance may be accounted for by the fact, that intercourse between animals is an act of instinct, and that an antipathy to intermixture with other species may be supposed to be implanted in the nature of all animals. But in plants there is no such thing as instinct; there is no power of avoiding one thing and searching for another; plants cannot travel from place to place in search of their mates; but where they stand there must they perform all the functions of their life, communicating their influence, be it what it may, to all bodies in their vicinity, and in their turn receiving the influence of others. Suppose two willows of distinct species standing near each other, and a gust of wind or a bee brings the pollen of one to the stigma of the other, what is to hinder that pollen from fertilizing the seed of the female; or the seed thus created of an intermediate nature between its two parents from falling to the ground, and then giving birth to an individual intermediate in its character between the male and female parents. It is quite plain, that the intermixture must inevitably take

place, and that in this manner something that had never been seen before will be produced. And there is no physiological reason whatever why this should not very often occur. It is true that the mule being barren will perish again in the course of time; but before it has disappeared it has been gathered, dried, and deposited in the herbarium of a Botanist, or, if a woody plant, it has been dug up, transferred to a garden, multiplied by cuttings, layers, &c., and dispersed through the gardens of all the finder's friends, as a *new species*, of the discovery of which he claims the *honour;* and then it finds its way into books. What is to be done with this vegetable monster? surely it ought not seriously to be raised to the rank of a species; and yet we find hundreds of things of such an acknowledged origin in the works of even De Candolle himself (see his *Prodromus Regni Vegetabilis*, vol. i. page 649), to say nothing of other cases; certainly we ought not to do this unless, indeed, we consider the Spanish mule a species distinct from the Horse and the Ass, which would be too absurd; we ought rather to strike them all out of systematic works, and to leave them to the care of the gardener, or those others who are interested in the preservation of such productions.

It is however a very embarrassing subject, this natural production of mules; for there is no known means of determining at first sight whether a plant is a mule or not. Professor Henslow found that a mule Digitalis did not exhibit the slightest anatomical organic difference from its parents. There is no means of judging with accuracy, even if the observer is acquainted with both its parents; and it is manifest that if acquainted with neither, or only one, the difficulty is still further increased. In some genera, as Rosa, in which the species cross each other very readily, the intermixture has been carried so far, that intermediate states may be produced from the most stunted state of *Rosa spinosissima* to the most gigantic form of *Rosa canina.* Willows, and probably many other large genera, are in the same predicament. From such cases as these, where no precise limits can be pointed out between species, some naturalists have proceeded to argue, that in reality species have no existence, that the vegetable world is a mere mass of individuals which we may arrange into groups called species, according to their likenesses, but which have no distinct qualities, and that the supposed limits between them are altogether arbitrary and imaginary. We think, however, that no necessity exists for this violent supposition, and that whatever evidence there may seem to be of its truth in particular cases, it is more than outweighed by other evidence. Take, for instance, in one of the most variable of genera, *Rosa*,—take the seeds of the common Sweetbriar, and sow, as we have often witnessed, an acre with them. All the plants in that acre of land will be botanically identical and referable to the same common form of *R. rubiginosa* from which they sprang. Probably not a single plant in all that acre will exhibit even a trace of a tendency to vary. Look again at the thousands of acres of Turnips that are annually raised in this country: who ever saw any instance of the slightest tendency on the part of those turnips to be any thing except the species Brassica Rapa, unless in those cases where the seed had been notoriously obtained from the intermixture of the pollen of the cabbage, or some allied species? And suppose such a monster to be created, either it produces no seed and perishes for ever, or, if it produces seed, that seed being sown, will produce plants returning to the species B. Rapa, from which it sprang. To deny the existence of species then, because of difficulties in determining the limits that separate them, is, independently of all other considerations, to argue in the face of the plainest evidence of their real presence. Naturalists are much more worthily employed in clearing up the difficulties that exist in the way of distinguishing species, than in accumulating doubtful instances of their transition into one another; a most mischievous theory directly opposed to the general evidence in both kingdoms of nature, " and useless, because, if it were true, we should be compelled to act as if it were false, under penalty of knowing nothing, and to study the habitual forms of vegetation just as we now do."

With regard to the uncertainty and difficulty that is obviously connected with the discrimination of species, De Candolle has some excellent remarks, the substance of which we shall borrow as a conclusion to this discussion. If the doubts that often exist as to the real

limits of species were as common as at first sight they seem to be, they would not only throw beginners into despair, but discourage the most consummate naturalists. But by a law that seems strange, though in reality it is very simple, nature has confined this indefinite tendency to variation to the most common species, or to those which are most extensively cultivated. For what in fact is a rare plant? It is a plant which is so organised, that it can only live in a particular locality, and which perishes in all others; such a plant is incapable of assuming different forms. What, on the other hand, is a common plant? It is a plant robust enough to exist in very different localities, and under very different circumstances, and which will therefore put on many different forms. Those first variations, once established, may be multiplied and increased, by hybridizing or other causes, and will become numerous in proportion to the quantity of individuals that may be created. Cultivation is one of the most efficient causes of the production of varieties, either because it multiplies so very much the external circumstances that surround a plant, or because, by bringing plants together, it increases their opportunities of muling. But a rare plant, that is, one which requires a particular locality, cannot be generally cultivated, and is thus cut off from the great source of variation. These considerations suffice to show, that plants are liable to run into varieties in proportion as they are more robust, more common, or more cultivated; as for instance, *Lotus corniculatus*, *Anthyllis vulneraria*, *Pyrus communis*. They also explain why certain exotics are more easily cultivated than some of our own native plants, such as Gentians, Pedicularis, and the like.

We cannot terminate this very important subject more usefully than by quoting some observations upon species by Mr. Bentham, a most sagacious and successful investigator of their real value in the order Labiatæ (*Lamiaceæ*), upon which an inconceivable amount of systematic trifling has been expended. "There seems every reason to consider that each species has a really distinct existence in nature, as a group of individuals, varying from each other only within the limits of individuals descending from one common stock; and the question is therefore here, *are* two plants of the same species or not? Of this it is seldom we can obtain positive evidence; we must reason by analogy — we must take into account all the varieties likely to be caused by soil, climate, and other external agents,— by cultivation, by hybridity, by disease, &c., as well as by the age and period of development of the specimen before us; — we must consider whatever circumstantial evidence we can deduce from station, from abundance of individuals resembling each of the two specimens before us, or from any other source we can get at; and from these data we must then form our judgment. This judgment may indeed be erroneous, even when pronounced by the most experienced Botanist possessed of the greatest number of data; how much more so must it be when a young Botanist, scarcely acquainted with the commonest plants of his own neighbourhood, sits down with a scanty library in a botanic garden, and publishes as new every specimen that does not exactly coincide with the descriptions of the plant whose name he finds appended to his specimens; or if, studying the wild plants of his own country, having no general herbarium, and therefore ignorant of the various forms a species may assume in other countries, he considers as specific distinctions any accidental variations to which a continuation of the circumstances which originally occasioned them may give, in his neighbourhood, a certain degree of permanency.

"I have been led into these observations as a sort of answer to those who may consider me presumptuous in setting up my opinions, formed, in a great measure, from dried specimens, against the observations of local botanists and directors of botanical gardens, often of great merit, who have studied the plants living. If, for instance, the principles upon which M. Host added 37 *Menthæ* to the Flora of Vienna were to be followed throughout, the number of Labiatæ now to be described would rather be 17,000 than 1700; these 17,000 descriptions would most of them, a hundred years hence, have to be replaced by as many others, and the whole would soon become a complete chaos. Already, many of the original plants upon which M. Host established his species, and most of their descendants, no longer possess his distinctive characters; and if this be the case with M. Host, how

much more must it be with those who, with all his national pride in the number of species comprised in his Flora, have none of his talent, and carry to so high a degree the sometimes mercenary and always foolish vanity of tacking so many *nobis* to botanical names.

"Some genera of Labiatæ are peculiarly liable to this multiplication of species. Very hardy and abundant in those parts of Europe where the real number of species has long been well known, the same species, growing in a great variety of situations,—in the dry roadside dust or in marshes, or even in water—in shady woods and in open commons—long cultivated in gardens, and carried out to all parts of the world—not only casual varieties, but more or less permanent races, have been formed in the *Menthæ*, *Thymi*, *Stachydes*, &c., which it is impossible with any certainty to distinguish from real species; and any disposition to make species may readily be indulged in to almost any extent. Hybridity, also, that great obstacle to the discrimination of species, is not unfrequent in *Mentha* and *Thymus*, and probably in some other genera; although in the greater number of Labiatæ, fecundation taking place at the moment of the expansion of the corolla, and the parts of fructification being more or less concealed, hybridity only ensues under very peculiar circumstances.

"Another great difficulty that occurs, in long-known variable genera, in distinguishing the species, is the impossibility of judging, from the numbers seen in herbaria, of the real proportion in the number of intermediate forms to that of each of two common forms which they connect. If a whole tract of country be covered with individuals of two distinct forms, with here and there some accidental intermediate, it is these intermediates that the collector will seize upon with avidity, almost neglecting the normal states, and, at any rate, neglecting to record the fact of their great disproportion."

Chapter III.

Of Genera, and of the Principles upon which they should be constructed.

Supposing species to be distinguished in the clearest manner, it would be impossible to study them as isolated objects; the human mind would never be able to comprehend so vast a multitude of distinct forms of vegetable matter. And indeed it would soon be obvious to the most superficial observer, that to attempt so impossible a task is unnecessary, for in many cases, species obviously collect into small well-defined groups, having certain common characters of agreement, notwithstanding their respective points of differences. Roses, Heaths, Clovers, Cinquefoils, Brambles, are familiar instances of such self-evident combinations; and it is found that similar, though perhaps less manifest groupes are to be met with throughout the vegetable kingdom, so that the whole number of species, large as it is, may be reduced to 7000 or 8000 such assemblages: these are genera.

A genus has been defined to be a collection of species which have in common a striking resemblance in the totality of their organs; or a collection of species resembling one another, more than they resemble anything else. It might perhaps be better described, for the above are anything but definitions, as a collection of species agreeing in the number, proportion, and general nature of the organs of fructification; and then every genus will be the representation of some special, simple type of organization, which differs from all other types; just as an order is the representation of some more compound type of organization?

Descriptions of this sort are necessarily vague and indefinite; and hence a great uncertainty in what should be considered the true limits of many genera, and an arbitrary mode of constructing them, that has led to much confusion. While some Botanists, as Linnæus, and most of the older writers, comprehended under one name extremely different kinds of structure, because of some common character that connected them, others, on the contrary, have constructed their groups upon such trifling distinctions, as to render the words species and genus almost identical terms. Both these classes of writers have been equally in the wrong.

Although we do seem to recognize genera, apparently ready-formed, amongst the vast mass of vegetable productions, yet it is quite certain that in a very large majority of cases they are mere contrivances to enable us to execute the first process of analysis,

by which the vegetable kingdom is systematized. Now the writer who constructs genera upon trifling characters, and thus reduces genera back into species, defeats the object we have assumed to be pointed at in constructing such groupes; they do not assist us in the process of analysis, and therefore are objectionable. On the other hand, the Botanist who combines plants with extremely different structures under one generic name, renders useless the analysis to which he leads us, by depriving his genera of any definite or intelligible meaning. It is clear that the right course is between these two extremes.

De Candolle maintains the somewhat singular doctrine that so long as a group of plants is *looked upon* as a mere section of some other assemblage, it may be considered one genus; but if it should turn out that it has been wrongly so looked upon, and that it forms a special assemblage of the next higher grade, namely an order, it may then be subdivided into a number of genera. If this really were so, it would render the limits of genera much more arbitrary than they really are, which hardly need be. But we think this doctrine cannot be supported. One would say that if plants differ essentially in structure, as the various groups of Lichens for example, they ought to be esteemed distinct genera, whether they together form a section of an order, or an entire and special order; and that the reason why Botanists formerly admitted such genera as Lichen, Orchis, Epidendrum, Geranium, &c., was, that they did not know of the remarkable diversities of organization that are now found to exist among their species.

Perhaps the best way to judge what a genus really is, may be to take such notoriously indivisible genera, as Rosa, Rubus, Fragraria, Potentilla, and Geum, and see by what it is that they are so positively combined that no one is now able to devise a method of subdividing them. Probably their example may be more instructive than the best verbal definitions.

In Rosa the calyx has a fleshy tube contracted at its orifice, with five leafy segments; the corolla consists of five thin coloured petals; the stamens are extremely numerous, and arise from just without the contracted orifice of the calyx; the carpels are numerous, distinct, one-seeded, hairy bodies, each having a single style and stigma, and all enclosed within the tube of the calyx, except the stigmas which project beyond it; the fruit is formed by the tube of the calyx becoming succulent, and the carpels change to bony seed-like nuts enclosed within it. The numerous legitimate species of this genus disagree in the form of their leaflets or the number, and in the nature of their prickles; some bear fragrant glands upon their leaves, others have their fruit armed with stiff bristles; others have the segments of the calyx equal, instead of partly unequal; and some again bear their flowers singly in the bosom of common leaves, instead of originating from bracts. Here then is a group of plants uniform in the plan of organization of their fructification, but differing in certain modifications of those parts, and of the organs of vegetation.

Rubus has the general characters of Rosa, only its calyx is *not contracted at the orifice* into a hollow chamber to contain the carpels, and never *becomes succulent*, but remains thin and dry to the last; its carpels, on the contrary, *have a succulent coating* when ripe, and are disposed upon a *conical dry receptacle* that projects beyond the open mouth of the calyx. Here are several important peculiarities that never occur in Rosa; and agreeing in such common characters is again a large number of species, some with simple, some with compound leaves; some with herbaceous, others with woody, some with unarmed, others with prickly stems; some having their leaves of one form, others of another. Rubus then is essentially distinguished from Rosa. Now, suppose, what really happens in Rosa Rapa, that a plant, *otherwise agreeing in all respects* with Rosa, has a campanulate calyx open at the orifice, could such a plant be separated as a distinct genus? Such an idea never has entered the mind of any one; for no one could pretend that such a difference could be of equal importance with those which separate Rubus from Rosa.

In Fragaria we have the structure of Rubus, except that the calyx consists of *two rows of sepals* instead of one; the carpels are *dry instead of succulent;* and the *receptacle succulent instead of dry;* in other words, the power of collecting fluid and saccha-

rine matter, which in Rosa exists in the calyx, and in Rubus in the carpels, is here transferred to the receptacle. These are very important differences connected with vital functions; and are manifestly of a higher order than diversities in the form, surface, and texture of the leaves, or the relative hairiness of different parts, by which the species are distinguished.

Then Potentilla is a Fragaria in all respects, except that its *receptacle is dry, not succulent.* Here indeed the difference between the two genera is confined to one single character; but then it is a character connected with the uses to which the species have been destined, and it indicates a total change in the nature of an important organ. Its numerous species are distinguished by peculiarities in the foliage, the stem, or the inflorescence, and in the *external forms* of the organs of fructification.

As for Geum it differs from Potentilla solely in its *styles becoming rigid and hooked,* instead of shrivelling up or falling off. This too is a single character, but what an important one it is! The style, a most essential part of the fructification, changes its office after impregnation, and, from being a fertilizing organ, becomes a peculiar means of disseminating the seeds to whose organization it originally contributed. Subordinate to this particular are strongly marked differences in the leaves, the calyx, the inflorescence, which indicate a number of species agreeing in the common character of the hardened style.

As a further illustration of this subject, a few spurious genera may be advantageously cited. Take the modern characters of Stachys and Betonica, two Linnean genera.

Stachys. Calyx ovate-campanulate, 10-ribbed, with 5 somewhat unequal mucronate teeth, the throat naked or somewhat naked. Corolla hardly projecting beyond the tube, with a prominent, entire, concave upper lip, and a lower spreading trifid one.

Betonica. Calyx between conical and tubular, 10-ribbed, with 5 equal mucronate teeth, the throat beset with stiff hairs. Corolla with a slightly curved tube projecting beyond the calyx, an ascending upper lip, and a lower hanging 3-lobed one.

What can be more slight than the differences between these? One has the calyx a *little more* campanulate, the teeth *rather less* equal, the corolla *rather longer*, and the throat of the calyx a *little more* hairy, and the lower lip of the corolla *rather more* pendent than the other. Nothing can be more trifling or unimportant than such distinctions. The two supposed genera are one and the same. It is upon similar puerile distinctions that the genus Trifolium has been divided into seven or eight by Presl, Erica into 14 or 15 by Don, and Œnothera into 10 or 12 by Spach. These are blots upon the face of science by which she is disfigured and disguised. In all such cases the authors have mistaken trifling superficial characters for fundamental, structural, or physiological ones; this, although it may seem a mere verbal distinction, is in reality a most important one.

Mischievous however to science as are the proceedings of mere genus-makers, hardly less injurious are those of persons who, clinging to old prejudices, would preserve the heterogeneous genera of our forefathers in their ancient state. Orchis, for example, they would keep as Linnæus left it; but the genus Orchis of the great Swedish Naturalist comprehends plants with many different contrivances for effecting impregnation, and with whole series of organs in one species which do not exist in another, and all these constitute particular categories of organization under each of which many species arrange themselves. There is no distinct meaning then in the Linnæan word Orchis, to which precision has only been given in modern days.

We again quote some practical remarks by Mr. Bentham upon this subject. Speaking of the course he has taken in his monograph of *Labiatæ* (Lamiaceæ), he says:—

" For the distribution of Labiatæ into genera, I fear I shall by many be accused of inconsistency in the importance I have attributed to the characters I have selected on different occasions, but this appeared to me unavoidable; for, although, as a general rule, certain characters are of an order superior to others, yet, in detail, there are too many exceptions in nature to allow a graduated scale of characters to be drawn up with any exactitude. Take an instance from one of those of the greatest importance, the entire or four-lobed ovarium, a distinction which, with scarcely any exception, draws a line

between two very extensive and natural families, the Verbenaceæ and Labiatæ. Apply the same rule to Boragineæ, and you must separate *Heliotropium* from *Cynoglossum*, *Cynoglossum* and *Echinospermum* from *Anchusa* and *Myosotis*, when a series of species might be selected from all these genera so near to one another in habit and other characters as to tempt one at first sight to consider them as forming but one genus.

"If I have, therefore, for example, on some occasions taken differences in the calyx, in the anthers, &c., as generic distinctions (the anthers of Sphacele and Stachys, the calyx of Thymbra and Melissa); at others, considered them merely as sectional or even specific distinctions (the anthers in Melissa, the bilabiate calyx in Stachys menthæfolia), it has been because, in the one case, they appeared to me constantly accompanying differences in facies and other characters, and at other times at variance with them. Besides which, I have always considered, that although certainly we do observe certain groups of plants more nearly allied to each other than to any others, and distinguished from their several affinities by a sort of hiatus, yet even now, many as are the species which remain to be discovered, it is often very difficult to say between which two species the hiatus is most marked, and the more plants we discover the more are these hiatuses filled up. A genus, therefore, has seldom any existence in nature as a positively determined group, and must rather be considered as a mere contrivance for assisting us in comparing and studying the enormous multitude of species, which, without arrangement, our minds could not embrace. But although our genera be not in nature, yet the nearer we follow what is in nature in grouping our plants, the more useful is our labour. Whenever two or more species resemble each other by all those characters which experience has shown us to be important, they should form a group of the lowest order. Where several groups resemble each other closely, but differ in some character of an order rather higher than those with which we separate species, they form a group of a superior order; and these again form groups of a third order, and so on, till we arrive at the general group Plants; but to which of these orders of groups we give the name of *genera*, and to which those of *order*, *tribe*, section, &c. is a matter of mere convenience.

If all existing plants were known, and it were always possible to say to which of the 1st, 2nd, 3rd, &c. order a group belongs, then it would be absolutely necessary to take care that the name *genera*, for instance, should always be given to groups of the same order; but in the present state of the science, at least, this is impossible. Take, for example, the group of Nepeteæ, which is very natural because a very marked one, offering (as at present known) no intermediates with others in regard to its essential characters; it comprises two groups distinguished from each other by slighter and more variable characters. One of these comprehends four of a still lower order; of these Nepeta comprises eight groups of a fourth order; and another (Dracocephalum) contains five, which are about of the same value as the eight of Nepeta, but which might be distributed into two or three intermediate groups. It would be just as natural to consider the whole of these as one genus, consisting of two sub-genera, seven sections, and eighteen sub-sections; or as two genera, one comprehending two sections, and the other four sub-genera and sixteen sections; or as I have done, as a tribe, containing two groups, one with a single genus, divided into two sections, the other with four genera, two of which are subdivided into sections; or if each of these sections were considered as a genus—provided that in all cases no groups be collected into one of a superior order, that are not more like each other than to any other group. Whenever, therefore, natural affinities appeared to leave it indifferent which of two courses I should pursue, I have, with few exceptions, considered as sections such groups as are distinguished by characters of no greater importance than stem, foliage, or inflorescence; and all characters taken from the organic structure of the parts of fructification have been considered as generic."

Nothing has, probably, given rise to so many heterogeneous genera as the famous Linnean axiom, a genus shall furnish its own character, but no genus can be founded upon a character (*Genus dabit characterem, sed non character genus*). That is to say, when a collection of similar species has been formed, some common character by which they may be combined is to be sought for; but a

peculiarity of structure is not to be first selected and then the species collected under it. It was apprehended that the latter practice would lead to the formation of merely artificial genera, and it was expected that the former would ensure the generic groups, being so natural that they might be recognized at first sight, independently of their technical character. De Candolle regards this axiom as the touchstone by which the goodness of genera is to be estimated. "It is by it that we are principally able to determine what are the really essential characters of each natural order; for instance, the calyxes of the larger species of Gentian possess strongly marked differences which would readily seem to form several genera; but the extreme resemblance of these plants one to the other obliges us to leave them united, and proves that the form of the calyx is of no importance in their order." *Théorie élémentaire*, ed. 2, p. 220.) Helm has sustained the proposition metaphysically, considering it of the utmost importance, and the very foundation of scientific knowledge. (*Dissertatio de Methodo physico-historicâ*, p. 78.) And to this we must add the authority of Fries. "In the formation of sections and genera it is most especially necessary to beware that they do not depend upon characters alone; so that if the character should hereafter prove defective, the section or the genus may still remain unchanged. In this lies the difference between an artificial and natural arrangement; the former depending upon characters, the latter upon affinity. Hence Linnæus did not characterise his families of plants, nor Ehrenberg those of Fungi, rightly perceiving that affinity is of the first importance, characters of secondary." *Syst. Mycol.* — Professor Lindley has however objected to it, and we think with reason. "Whether or not," he says, "this proposition is to be admitted, depends entirely upon the nature of the character employed; for if the character is one of fundamental importance, it is absolute, and that which defines the group; but if it is unimportant, it is unfit for any sectional purpose and ought to be rejected. For instance, to have their trunk growing in the centre is the character of Endogens; and who would think of removing from those plants Smilax or Dioscorea, because the appearance of the latter is that of Menispermum, or some Euphorbiaceous genus among Exogens (?)" (*Nixus Plantarum*, p. 4.) We follow on the same side.

It is said that after a genus has been made by collecting together a number of species greatly resembling each other, a character is to be found to combine them; that is, in the first instance a genus is to be formed upon some vague and indefinite notion of natural resemblance, and after that has been accomplished, a positive combining character is to be discovered. But we would ask what is meant by a natural assemblage, or by strong botanical resemblances? unless a strict correspondence in organization; and what can so strongly indicate that, as conformity in fundamental points of structure, or, in other words, in important characters? Botanical resemblances depend then for their very existence upon what Linnæus called a character, and therefore it seems to us that his proposition should be reversed, and that we ought to say that *characters form the genus, and not the genus the characters*. If we are to trust to vague external resemblances for forming a preliminary idea of a genus, all scientific precision is abandoned. A common observer sees a great and close similarity between an Ash Tree, a Walnut Tree, and a Sumach Tree, or between a Hazel Bush (*Corylus*), a Witch Hazel (*Hamamelis*), and many Grewias; but in reality these plants, however natural their grouping may seem to be, have no botanical affinity, but merely correspond in certain unimportant superficial particulars. On the other hand, a common observer can see no great resemblance between the common European Nettle and many of the arborescent Nettles of the Tropics, and he would never dream of their forming a natural genus; and yet they really correspond in every one of the essential characters of their organization. Let no one take alarm at this heresy; for if important characters are made the basis of generic distinctions, no unnatural or heterogeneous assemblages can be the result; the necessary and inevitable consequence of employing important structural characters, *independent of all other considerations*, is the collection into genera of species resembling each other more than they resemble anything else. This is proved in the clearest manner by the genera so constructed by Brown, De Candolle, and others, the highest

modern authorities we have. Brown has divided his New Holland Epacridaceæ, Orchidaceæ, Cyperaceæ, Myoporaceæ; De Candolle his Brassicaceæ, Apiaceæ, Cinchonaceæ, and Compositæ entirely according to their structural characters, and not according to the general appearance of the species; but the latter coincides with the former as we have asserted that it would; and we attribute the great and universally acknowledged excellence of Brown's generic characters to his having virtually abandoned the Linnean axiom now in discussion. And so have and must all writers who would lay any claim to precision. When the Linnean method is adopted, the consequences are of the following nature: A plant is discovered which is in reality organically distinct from all known genera; but it has some *resemblance* in structure to a known genus, and it *looks a good deal like it;* the botanist who follows up the maxim of Linnæus stations the plant in that genus, although it is essentially at variance with the character of the genus; and at the same time gives it a name which does not belong to it. This is as if, in society, a person were to call his son John Brown, because he resembled an acquaintance whose name was Brown, although his own name was John Green; in such a case no one could discover that John Brown belonged to the family of John Green. Here the absurdity is obvious, and yet it is not seen when applied to Natural History; or we should not have in the writings of botanists such passages as the following upon the occasion of placing a plant in a genus with whose character it does not correspond. "I refer this plant to the genus Eumorpha, in consequence of its great resemblance in habit to Eumorpha patens and grandiflora; it must be confessed, however, that its fructification is far from corresponding with that of the genus in question." That is to say, it is referred to the genus, *although it does not belong to it.*

While we thus contend against the principle of combining dissimilar things because of some vague common point of agreement, we would nevertheless caution the student against embarrassing the science by a display of his ingenuity in detecting little characters by which it is possible to break up old and long recognized genera into smaller groups. After all that can be said concerning the limits of genera, and the principles upon which alone they ought to be constructed, there must still be something in those principles vague and undefined, and which must be left to the judgment of the systematic botanist; and therefore expediency may occasionally be consulted in doubtful cases. There is very great inconvenience in changing the names of large numbers of species, as must be done in extensive alterations of old and long established genera; for example, the spurious genera created by one Spach in a silly scheme for remodelling the genus Œnothera, would cause for that one genus the abolishment of 49 names and the creation of 63 others. Proceedings of such a kind increase extremely the necessarily very considerable difficulties connected with so intricate a branch of science as systematic botany, and therefore should be taken with great caution and only in cases where they cannot be avoided: for so long as such a word as Œnothera has a precise value, there is no inconvenience in employing it, even although it should appear that a possibility exists of making it something more precise; while there is the greatest practical inconvenience in admitting so many changes in nomenclature as its subdivision would render necessary. But when we find a man introducing confusion by cutting up a well defined homogeneous and long established genus, because in some species the seeds have a thicker skin than in others; because the seed-vessel is in some narrow and in others broad, in some tough, and in others tender; in some 4-ribbed, in others 8-ribbed, and in others 12-ribbed; when we find a man acting thus—we may, without much risk of error, set him down as a verbal trifler, of unsound judgment, with no general views, and who is incapable of perceiving the distinction between fundamental differences of organization and slight modifications of one and the same type of structure.

In order to ensure some uniformity in the construction of genera, it is usual that whatever in any one natural order is taken as a generic character for one genus, should be also taken for all other genera *in the same order;* as for example, when in Orchidaceæ the number of pollen masses is within certain limits taken as a distinctive mark of certain genera, similar differences in number in the same organ should be

looked upon as absolute in all other genera of the same order. In the words of De Candolle, "whenever a particular character has been employed to separate a certain number of genera, it ought to preserve the same importance in all similar cases, that is to say, it must, according to circumstances, either unite genera separated by a single character, or separate species from genera to which they would have been referred if it had not been for that character; thus in Compositæ, botanists are agreed in admitting a setaceous or a feathery pappus as absolute distinctions of certain genera: those modern writers have consequently been right who have broken up certain genera of Compositæ in which species with both setaceous and feathery pappus had been heaped together." To the justice of this doctrine we cannot but assent; for it is the only certain means of rendering generic distinctions consistent and of the same value in the same natural order. It must, however, be observed that in proportion as this doctrine is absolutely pressed upon the botanist, does it become requisite to ascertain that the distinctions thus taken as peremptory indications of genera are unquestionably important, otherwise false genera without end will be created. For instance, what numberless genera of Cruciferæ, Umbelliferæ, and Compositæ will have to be suppressed, if it should ever be discovered that the characters of the embryo, the vittæ, the albumen, or the double pappus of those orders respectively, are of less value than they are now estimated at!

When genera were first put into their modern form by Tournefort, that botanist drew their characters partly from the fructification and partly from the organs of vegetation. Linnæus, on the contrary, repudiated the latter as uncertain, and insisted upon the necessity of attending exclusively to differences in the parts of fructification; and his example has been very generally imitated. Nevertheless, this rule may be followed too rigorously, for, as Jussieu has truly remarked, "it is not always conformable to nature, which not unfrequently places certain characters in the stems or leaves above others taken from the stamens, or the pistil, or the floral envelopes. Thus, the character of opposite leaves is more constant in Valerian and Gentian than that of the three stamens, in the first of those genera, and of five in the second. The leaves are always alternate in the Larkspur and the Pæony, but the number of their ovaries is variable. The corolla is both absent and present in Ashes and Maples, but those trees have universally opposite leaves." These instances, which might readily be increased, suffice to show that several characters in the fructification are sometimes of less importance than others which are independent of it.

With regard to the value that is assignable to the different peculiarities by which genera are to be characterized, this depends so very much upon circumstances, that it is rather a matter to be determined by experience than regulated by certain laws. Nevertheless the following rules are deserving of serious consideration:—

1. A character is important in proportion as it is connected with modifications of function.

2. A character is unimportant in proportion as it is connected with modifications of texture, proportion, number not in extremes, form, and the like.

3. Excellent distinctions are those connected with numerical proportion, absence or presence of certain classes of organs, relative position, decided differences in the degree of adhesion of organs, regularity and irregularity, high developement or low developement, tendency to loss of parts, and so on.

4. "Characters are not to be estimated as so many units, but each according to its relative value; so that one single constant character may be equivalent or even superior to several inconstant ones taken together."—*Jussieu.*

Tried by rules of this sort, not a few long-established Linnæan genera may be found wanting, as in Silenaceæ and perhaps Malvaceæ; but this will, we think, in the eyes of botanists, rather attest the goodness than show the invalidity of such principles.

Chapter IV.

Of Orders; Alliances; Groups; or other systematic Combinations subordinate to Classes.

It has already been said, that while a genus may be understood as the representation of some special simple type of organization, an order is the representation of a more compound type of organization to which the genus is sub-

ordinate. In reality, orders, groups, alliances, or by whatever names such assemblages are called, are combinations the one of the other, formed upon the same principles as genera, and may be considered as genera of ascending importance. As there are genera which, like Rosa, Quercus, and Rubus, seem actually to be formed by nature herself, although others are confessedly artificial assemblages, so are there orders like Galiaceæ, Apiaceæ, Brassicaceæ, and alliances like Echiales, Chenopodales, and Lamiaceæ, and groups like Labiosæ, Aggregosæ, and Glumosæ, which bear a similar impress of original separation from the others that surround them. Nevertheless we are only justified in considering all such combinations as assemblages of genera, orders, or alliances which resemble each other more than they resemble any thing else.

Such words as genera, orders, alliances, groups, &c., are then conventional terms, having the same general meaning, and differing only in degree, just as villages, hundreds, counties, kingdoms, and empires, or any such relative expressions. So true is this, that many of them have been genera in the eyes of former systematists; instances of this are Fungi, Ferns, Palms, Grasses, Lichens, Mosses, &c.

In the construction of these groups, the great point is to keep steadily in view the necessity of preserving a strict conformity in the essential parts of fructification, and not to confound mere instances of analogous organization with real affinity. Affinity is indicated by an accordance in all points of structure, except such as are taken as discriminative of genera; analogy consists in an accordance between one or two parts only. If this is not attended to, errors without end are the inevitable result. Thus when Professor Don allowed himself to be deceived by some analogies between Menodora and Columellia, he committed the error of uniting in one order a plant which in reality belongs to Jasminaceæ, and another that comprehends a special and peculiar type of its own; and most of the cases of errors about the natural orders to which plants belong, are referable to the same cause; witness Calycandra, a leguminous genus placed in Capparidaceæ; the curious genus Moringa, once referred to Leguminosæ; Lutkea, a Rosaceous genus stationed in Saxifragaceæ; Adoxa, an Araliaceous genus, till lately kept in Saxifragaceæ, and so many others.

Chapter V

Of Classes; and the Nature of the Characters upon which they are founded.

Classes are the fundamental divisions of the vegetable kingdom, representing the largest aggregations of species, and expressing the most essential combining characters which they possess. They are by many considered merely as a higher order of division, and analogous to orders, alliances, groups, and so on. While, however, the latter are indisputably mere artificial groups of naturally related genera, it seems probable that classes have some real existence in the original plan of nature. As in animals, the great classes of Quadrupeds, Birds, Fishes, Reptiles, and Insects, stand like isolated groups, which might almost be considered independent kingdoms; so do Exogens, Gymnosperms, Endogens, Rhizanths, and Acrogens, each also appear to be created by nature as altogether independent forms of organized matter.

The distinctions of groups like these are not confined to mere variations in certain types of organization, as is the case with the assemblages subordinate to them; but they are founded upon corresponding differences in the manner of growth, of propagation, of circulating the fluids, of reproduction, and even of elementary anatomical structure; in short they depend upon peculiarities connected with their whole nature, and not with mere modifications of particular parts.

If this distinction is a just one, we think it can hardly be doubted that the great fundamental divisions of the vegetable kingdom are altogether of another nature from the subordinate ones; and that while the latter are necessarily to a certain extent artificial, the former are literally natural, and a part of the original plan of the creation. This perhaps may be made clearer by a comparison.

The *class* of Exogens is

1. Constructed with both spiral vessels and cellular substance.
2. Furnished with sexes.
3. Grows by augmentation of the diameter of the axis.
4. Propagated by seeds.
5. Germinates from two definite points of its embryo.

The *class* of Acrogens is

1. Constructed of cellular substance chiefly, without spiral vessels.
2. Destitute of sexes.
3. Grows without augmentation of the diameter of the axis.
4. Propagated by spores.
5. Germinates indefinitely from any part of the surface of the embryo.

Every one of these five peculiarities is connected with the habits of life, manner of growth, or power of multiplication, that the plants in these two classes severally possess. Contrast with these the distinctions between two of each of the assemblages of different degrees, subordinate to the classes and above the genera.

A. The *sub-class* of Monopetalous Exogens has	The *sub-class* of Polypetalous Exogens has
1. The petals combined into a tube.	1. The petals distinct from each other.

B. The *group* Epigynosæ of Polypetalous Exogens has	The *group* Parietosæ of Polypetalous Exogens has
1. Ovary inferior, with either parietal or central placentæ.	1. Ovary superior, with parietal placentæ only.

C. The *alliance* Onagrales of Epigynous Exogens has	The *alliance* Myrtales of Epigynous Exogens has
1. All the parts of fructification symmetrically disposed upon a binary type.	1. The parts of fructification unsymmetrical.

D. The *order* Combretaceæ has	The *order* Alangiaceæ has
1. Petals short and roundish.	1. Petals long, linear.
2. Anthers versatile.	2. Anthers adnate.
3. Albumen absent.	3. Albumen fleshy.
4. Cotyledons convolute.	4. Cotyledons flat.

We have been constrained to take these cases from Professor Lindley's Natural System, because no other English botanical writer has attempted, upon any fixed plan, to depart from the artificial subdivisions of Jussieu and De Candolle. Such examples are, we presume, sufficient to show that there is an essential difference between the classes and other divisions of the vegetable world.

Chapter VI.

Of the Transitions that are observable between the different assemblages in the Vegetable Kingdom.

That there is no such thing in nature as an abrupt transition (*saltus*) from one thing to another, has long been a favourite speculation with philosophers, and has not failed to be applied to natural history. Ray, in the preface to his "Historia Plantarum," remarks, that "as nature never passes from one extreme to another, except by something between the two, so she is accustomed to produce creations of an intermediate and doubtful condition, which partake of both extremes, and so completely connect them, as to render it altogether uncertain to which they most belong."

This truth could hardly be appreciated by the naturalist who was conversant only with the natural productions of some small portion of the world, and it would be the more readily rejected by such a person, because, if true, it would obviously go to the annihilation of all definitions in natural history; for if every object is admitted to pass into some other object by an insensible gradation, it would be necessary to admit also that no real limits are to be found between one thing and another, and that absolute distinctions can have no existence.

But so many evidences of the truth of this theory are daily forcing themselves upon the mind of a naturalist to whom all the varied forms of species in different climates are submitted for examination, and who finds it, in a multitude of cases, so utterly impossible to frame any verbal or ideal definitions to which there shall be no exception, that he is constrained to recognize the doctrine of transition, at whatever inconvenience to the study of the science; not however applying it to species, for among them, as has already been shown, apparent transitions are chiefly accidental, but confining it to each and every combination above species, and inferior to classes. This is so true, that Linnæus is recorded to have confessed to one of his friends that he could not tell what constituted a genus; and Jussieu, in the preface to his "Genera Plantarum," declares that, as to a genus, there can be no certain definition of such a thing, nor any accurate directions given for the construction of it in

the natural system, *because species are collected together by their affinity in so imperceptible a web*, that the only meaning that is to be attached to a natural genus is, that it keeps together (prevents the separation of) species naturally related to each other, and does not interrupt the order of their arrangement.

A few common instances will illustrate this. A strawberry is apparently a very different genus from a Cinquefoil; yet if a species occurs with all the characters of Fragaria, but without the succulence of its receptacle, such a species becomes a Cinquefoil; this happens in Fragaria sterilis, now called Potentilla Fragaria. Amygdaleous plants are distinguished from Pomeæ by their solitary carpels and hydrocyanic acid; but some varieties of Prunus have several carpels, and Cotoneaster microphylla, a Pomeous plant, has hydrocyanic acid; in these instances there is a double transition. Nothing can well be more dissimilar than a Bean and an Almond tree, and both are types of certain natural groups: but Fabaceæ, to which the Bean belongs, exhibit so many gradations of structure, that at last they pass into a plant called Detarium, which has the drupaceous fruit and icosandrous stamens of Amygdaleæ; so that if an Amygdaleous plant should be discovered with pinnated leaves, there would no longer be a positive distinction between that group and Fabaceæ. In Lamiaceæ, the ovary is deeply divided into four lobes; in Verbenaceæ it is undivided. This, if permanent, would positively distinguish two natural groups in most respects much alike; and it really does form the only structural difference between them; but in Verbena itself the ovary is slightly lobed; Chloanthes, a Verbenaceous genus, has the habit of Lamiaceæ, and Hoslundia, a Lamiaceous genus, has the habit of Verbenaceæ.

To cases of this sort there is in fact no end. On this account some botanists have come to the conclusion that in characterizing the groups between the highest (classes) and the lowest assemblages (species), it is better to give up all attempts at definition, and to substitute brief descriptions of the *prevalent or typical characters*, considering all the minor groups as mere *tendencies* (*nixus*) towards this or that form of organization, the general nature of which is susceptible of description, but the precise nature of which is incapable of definition. Generic and ordinal characters are in this view mere expressions of certain ideas connected with structure; and plants will correspond with those ideas more or less in proportion as they approach the typical form in their organization. This view, which has been taken by Professor Lindley in his "Nixus Plantarum," and subsequent systematic works, is founded upon the theory well explained by Fries, that our conceptions of the nature of genera, orders, and similar collections of species, are most correctly expressed by a sphere, the centre of which represents typical organization, with rays (or deviations) proceeding from it on every side.

"Let us imagine," he says, "all nature to be an immense sphere, with rays converging in the *centre*, where they finally become confluent in a point, which may be called the point of *identity*. This point comprehends the perfection of all the rays; for that the most perfect and most completely formed creations, as the sun, are always situated in the centre, is testified by all authority, by all experience. The powers of nature, diverging from each centre in polar opposition, are continually passing into opposite series. A new sphere is formed by each opposition, whence the highest (most perfect) sphere is again and again resolved into new spheres, which form wholes of themselves, and each of which, according as its power is a more or less perfect evolution, in itself represents the whole in a more or less distinct degree. The centres of these spheres may be exceedingly distant from each other, but their rays always impinge upon the rays of some other sphere: hence those which run into each other are not the most perfect forms (*summa*) of each section, but the least perfect (*infima*)."

The imaginary points where the supposed rays cross each other are the stations of transitions of whatever kind; and supposing the spherical theory to be admissible, transition cases must necessarily exist in all directions.

This speculation is at variance with a more common one, that all organic beings are created in an ascending or descending series of developement; that, for instance, starting from man, the most perfect of all animals, an uninterrupted series of forms will be discovered down to mere microscopic animalcules; or

that between a forest tree and vesicular confervæ there exists an uninterrupted chain of beings, connecting the one with the other by insensible transitions. Bats, it has been said, form the transition from mammalia to birds, web-footed birds pass to reptiles, sponges combine polypes with vegetables, and the theory has been pushed so far as to assert, that the diamond forms the passage from the vegetable to the mineral kingdom. This speculation will probably find few advocates at the present day, so entirely is it opposed to facts, if taken in the form in which it was originally propounded; but if it is modified so far as to apply not to one series but to many series, it then at once explains and sustains the theory of Fries, whose observations upon this subject deserve to be quoted.

"All natural bodies originate in successive developement, yet in a continuous series within a determinate sphere. Every new sphere originates in a digression from a series which is otherwise continuous. Whenever a more perfect sphere is separated from one which preceded it, and has acquired a higher station than its parent, it may be itself pressed down by such new ones as emerge from itself; but the depressed sphere is also capable of continuation in its descent; and under this mode of developement the same principles and the same types are regenerated under more perfect forms in the higher spheres."

"Those, therefore, are mistaken who assume that nature proceeded in a simple series to her most perfect productions. Thus, for example, all parasites, both animals and plants, must necessarily have been created later than their matrix (and should therefore be the most perfect parts of the creation). But Fungi, which are the latest in the series of vegetable developement, are the most simple of all in their structure. As the evolution of the animal and vegetable kingdom may be said to have proceeded with nearly equal paces, so the different sections of vegetables cannot be said to have arisen out of a simple series, but out of parallel or radiant series. Many Algæ must have been created more recently than the most perfect plants, Entozoa than the most perfect animals."

Chapter VII.

Of the value to be assigned in Systematic Botany to the characters used in the construction of the assemblages intermediate between classes and species.

It will probably conduce to the practical application of the principles hitherto explained, if some statement is made of the general value of the characters that are most commonly employed in forming genera, orders, and other assemblages superior to species and below the classes. It is expected that, although this may be a very dry and uninteresting subject, it will be useful to a student who can have no experience to guide him in determining what points of structure are most or least essential in a given case.

The root, properly so called, offers no characters that have been found uniform in particular families; in fact, the modifications of which it is susceptible are so few, that it is difficult to conceive in what way they can be applied. Certain forms of root-like stems and buds have, however, been observed, to which some attention should be paid. In the first place, neither bulb nor rhizoma is known in Exogens, while in Endogens they are sometimes characteristic of particular orders. Thus, all Marantaceæ and Zingiberaceæ and most Iridaceæ have a rhizoma in one form or other, and bulbs are a usual character of Liliaceæ and Amaryllidaceæ; in the former, however, the bulb is often represented by a rhizoma, or cormus, as in Brodiæa, Leucocoryne and their allies, or by those succulent fibres called fasciculate roots, as in Asphodelus itself; and in the latter the bulb is sometimes entirely absorbed by succulent perennial roots, as in Clivia.

External variations in the figure of the stem are sometimes available as distinctions of orders. Thus, a twining stem is, almost without exception, found in Menispermaceæ, a square stem is universal in Lamiaceæ, and an angular one in Galiaceæ; but more frequently its figure affords no indication whatever of affinities.—Texture of the stem is of scarcely more value. Cactaceæ, it is true, have always the cellular tissue in excess; but even in this order, the Pereskias are scarcely more succulent than other plants; and Euphorbiaceæ and Asclepiadaceæ exhibit instances both of the most decided state of succu-

lence, and of the normal condition of stems in general.—In the internal arrangement of the layers of stems, not many modifications have been observed beyond those already noticed as distinguishing classes; nevertheless there are some that deserve serious attention. In Aristolochiaceæ there are no zones to the wood; in Piperaceæ and Nyctaginaceæ there is a structure almost intermediate between that of Exogens and Endogens, out of which Schultz has proposed to form a new class (*Natürliches System des Pflanzenreichs*); Passifloraceæ are exceedingly remarkable for having their woody system nearly cut into equal quarters; and Calycanthaceæ are known by the presence of four incomplete centres of vegetation surrounding the principal one, and so forming four angles which are visible externally. — (See *Mirbel's figure, in the Annales des Sciences*, vol. xiv. p. 367.)

The leaves are subject to modifications which, in determining the mutual relations of plants, are not less important than the functions which they perform in the vegetable economy. Their characters depend upon their relative position, their degree of division, their venation, and the presence or absence of pellucid dots within their substance. All Cinchonaceæ have opposite entire leaves; in Lamiaceæ, Apocynaceæ, Gentianaceæ, Monimiaceæ, and many others, they are also uniformly opposite; but in the genus Fuchsia, in which they are usually opposite, species exist in which they are not only alternate, but both the one and the other on the same plant; and alternate leaved species exist in Aggregosæ, Scrophulariaceæ, and Malpighiaceæ, the leaves of which are generally opposite. In Corylaceæ, Apiaceæ, Ternströmiaceæ, Hamamelaceæ, and Urticaceæ, they are uniformly alternate; but in Combretaceæ, Ericaceæ, and Fabaceæ, orders usually having alternate leaves, they are occasionally opposite. We hardly know how far this irregularity is connected with the following observations of Schlechtendahl, which, however, deserve attention. "Those leaves," he says, "which are connected either by their base, or by the intervention of a stipule, I call opposite; and those which are not so connected, spuriously opposite (pseudo-opposita). Opposite leaves are never disjoined (Cinchonaceæ and Silenaceæ); spuriously opposite ones, which are much more common, being easily disjoined, readily become alternate. Branches obey the same law as the leaves."—*Linnæa*, i. 207. Some Ranunculaceæ (Clematis) and many Asterales seem to offer exceptions to the statement. — All Spondiaceæ, Rhizobolaceæ, &c. have compound leaves; in many others they are always simple; and in such orders as Aceraceæ, Aurantiaceæ, Geraniaceæ, Rutaceæ, and Sapindaceæ, both simple and compound leaves are found. This character, therefore, is not considered of so much value as many others. Neither is the degree of division of the margin usually important, toothed and entire leaves being often found in the same order. Nevertheless there is no instance of toothed leaves in Cinchonaceæ, Gentianaceæ, Clusiaceæ, or Malpighiaceæ; and they are very rare in Endogenous plants.—Characters derived from the arrangement of veins are known to be in many cases of the utmost importance; and it is probable, that when this subject shall have been more accurately studied, they will be found of even more value than has been yet supposed. It is already known that the internal structure and peculiar growth of Exogens and Endogens are externally indicated by the arrangement of the veins of their leaves,—those of Exogens diverging abruptly from the midrib, and then branching and anastomozing in various ways, so as to form a reticulated plexus of veins of unequal size; while those of Endogens run straight from the base to the apex, or diverge gradually from the midrib, not ramifying in their course, but being simply connected with each other by transverse bars, examples of which are afforded, on the one hand, by the Rose, and on the other by the Iris and Arrow-root. Although a few exceptions exist to both these rules, yet the general characters of the leaves of those classes are such as we describe. But independently of this, many other orders are distinguished by modifications of venation. Thus, all Melastomaceæ have three or more collateral ribs connected by branched transverse bars, something in the way of Endogens; all Myrtaceæ have one or two fine veins running parallel with the margin, and just within it; most Corylaceæ have the principal lateral veins running straight out from the midrib to the margin; Betulaceæ are distinguished

by this among other characters from Salicaceæ; and the same peculiarity separates the genuine genera of Dilleniaceæ, called Delimeæ by De Candolle, from those of which Hibbertia is the representative. All Gentianaceæ, whose leaves are broad enough to have more veins than the central one, are rib-leaved.—Leaves which contain reservoirs of oily secretions, indicated by the presence of pellucid glands within their substance, are almost always universal in a given order. Thus, Myrtaceæ, properly so called, (with the exception of the paradoxical Pomegranate,) are distinguished by these glands from Melastomaceæ; in one genus of which, however, (Diplogenea,) slight traces of them are to be found: they are present in all Aurantiaceæ; by this character Winteraceæ are distinguished from Magnoliaceæ, Amyridaceæ from Connaraceæ, &c. &c. Samydaceæ are remarkable for their dots, being partly linear and partly round. In the orders Phytolacaceæ, Petiveraceæ, Lamiaceæ and Zygophylalceæ, there are, however, genera with and without pellucid dots. —The secretions of plants are rarely attended to in any other cases than those just mentioned, except when a milky fluid, generally indicating poisonous properties, is present; but to the presence or absence of the latter a good deal of importance is attached, perhaps not very correctly. Milk is characteristic of Papaveraceæ proper, of the Artocarpeous section of Urticaceæ, of Euphorbiaceæ, Apocynaceæ, and several other groups; but it also occurs in some Apiaceæ, and is not discoverable in those orders to which it is proper except at particular periods of the year. Some Acers (platanoides, macrophyllum and Negundo) milk; others (pseudo-platanus, &c.) do not milk. It has been said to be universally absent from Endogens, but it is abundant enough in the roots of Alisma Plantago, in Limnocharis, &c.

At the base of some leaves are frequently found little membranous or foliaceous appendages, called Stipules, which are in fact leaves in an imperfect state of developement. Their presence may therefore be understood to indicate a peculiar degree of composition in the leaves to which they belong, and they sometimes indicate affinities in a very remarkable manner. In studying them, however, care must be taken not to confound genuine foliaceous appendages, to which alone the name of stipules properly appertains, with dilatations, or membranous or glandular processes of the petiole, such as are found in Ranunculaceæ, Grossulaceæ, Apocynaceæ, Apiaceæ, and others. The presence of stipules is universal in Cinchonaceæ, which are thus distinguished from Galiaceæ, in Betulaceæ, Salicaceæ, Magnoliaceæ, and many others. The orders Cistaceæ, Saxifragaceæ, Loganiaceæ, and Rosaceæ, are among the few cases in which genera exist both with and without stipules.

The starved leaves found at the base of many flowers, and technically called Bracts, are rarely employed as distinctions of orders, offering scarcely any modifications of importance. In Brassicaceæ, however, they are never present, and in Marcgraviaceæ they are usually hollow, being folded together by their two edges, like the leaves of which carpels are formed.

Forms of Inflorescence are occasionally, but not often, found characteristic of particular tribes. Thus all Asteraceæ, Calyceraceæ and Dipsaceæ have their flowers in heads; all Apiaceæ bear umbels; all Plantaginaceæ, Cyperaceæ and Graminaceæ, have dense simple imbricated spikes; all Betulaceæ, Corylaceæ and Salicaceæ bear catkins; Pinaceæ have a strobilus or cone; and all Echiales have a gyrate inflorescence.

The calyx is used in a variety of ways to distinguish orders; but the characters it affords are far from being of equal or uniform importance. Its absence implies the absence of the corolla also, which cannot possibly be present when the calyx is away, unless, as in Compositæ, it is obliterated by the pressure of surrounding bodies. By its absence all the orders called Achlamydeous are characterized, such as Salicaceæ, Piperaceæ, Saururaceæ, &c.; but in Betulaceæ it is present in the male flowers, and in Euphorbia itself; among Polypetalous Dicotyledons it is wholly wanting. These exceptions do not, however, affect the general importance of characters derived from its presence or absence. If it is unaccompanied by the corolla, plants are said to be Monochlamydeous, and this is a point of pretty uniform value. We know of no true Monochlamydeous orders in which the presence of a corolla forms an exception, unless the faucial scales of Thymelaceæ are considered the rudi-

ments of a corolla.—The sepals or leaves of which it is composed are either distinct or combined; and from this circumstance, characters are sometimes advantageously derived. Thus in Scleranthaceæ and Silenaceæ the calyx is always monosepalous; in Frankeniaceæ it is constantly ribbed, &c.—The number of sepals is sometimes a character of importance, as in Brassicaceæ, in which they are always four, in Papaveraceæ, which have rarely more than two, and in the greater part of Endogenous plants, which have usually three. This character, however, requires to be used with circumspection, as there are more instances of the number of sepals being variable than regular. Thus in Linaceæ and Malvaceæ they are three, four, five; in Clusiaceæ, they vary from two to six; in Homaliaceæ, from five to fifteen; and in Samydaceæ, from three to seven.—The æstivation of the calyx is always to be well considered, as certain forms are often among the best known indications of affinity. Malvaceæ, Tiliaceæ, Elæocarpaceæ, Tremandraceæ, Sterculiaceæ, have it exclusively valvate among polypetalous dicotyledons with hypogynous stamens; Ternströmiaceæ and the rest of the calycose group of Exogens have the sepals constantly imbricated in a particular way; Vitaceæ have the lobes of the calyx distinct and wide apart from a very early period of their existence: but in Penæaceæ both valvate and imbricate æstivation exists.—In some plants the sepals are of equal size; in others they are very unequal either in form, direction, or texture; in the former case they are said to be regular, in the latter irregular, and by this difference certain orders are characterized. Thus Sapindaceæ and Polygalaceæ have a calyx constantly regular; but it frequently happens that both regular and irregular calyces co-exist in the same order, as in Rosaceæ, Lamiaceæ, Fabaceæ, and many others.—In most orders the sepals form one series only; others have them in two rows, and this has not been found to be connected with any material differences otherwise; but when the number of series is increased much beyond two, they cease to be separately distinguishable, and form an imbricated calyx, which is frequently confounded with the corolla, as in Calycanthaceæ. We know of no order in which genera with an imbricated calyx of this kind and a common calyx co-exist. It is one of the principal points which separate Calycanthaceæ from Rosaceæ.—The most important character connected with the calyx is, however, its cohesion or non-cohesion with the ovary; or, as botanists incorrectly call it, its being superior or inferior. Some orders are positively characterized by this, as Asteraceæ, Apiaceæ, Caprifoliaceæ, Orchidaceæ, and many more; and as it often happens that it exists without exception, it thus becomes a useful means of distinction. Scævolaceæ are, for instance, by this means at once known from Brunoniaceæ, and Cinchonaceæ from Apocynaceæ. No instance of a superior calyx has been found in Ranunculaceæ, Brassicaceæ, Papaveraceæ, Rutaceæ, and a number of others. But there are some singular exceptions to this rule. Thus, among Anonaceæ, an order with indefinite superior ovaries, we find Eupomatia, in which they are inferior; in Melastomaceæ all degrees of cohesion take place between the calyx and the ovary; and in Saxifragaceæ this uncertainty of structure is still more remarkable. It should, however, be observed, that in the two latter orders the tendency to cohesion between the calyx and the ovary may be almost ascertained by careful dissection; and even in Parnassia, an anomalous genus which is referred to Saxifragaceæ, usually having an ovary completely superior, there exists a species in which it is partially inferior. We have said that the difference between a superior and inferior calyx consists only in the cohesion of that organ with the ovary in the one case, and its separation from it in another; and this is the view which is always taken of it, all that part which intervenes between the segments and the pedicel being considered the tube of the calyx. But it is to be suspected that theory has carried botanists too far, and that there are cases in which the apparent origin of the calyx is the real origin. Upon this supposition, what is now called the tube of the calyx may be sometimes a peculiar extension or hollowing out of the apex of the pedicel, of which we see an example in Eschscholtzia, and of which Rosa and Calycanthus, and perhaps all supposed tubes without apparent veins, may also be instances. In this case the whole of our ideas about superior and inferior calyxes will require modification.

The second floral envelope, or the corolla, consists of a number of leaves equal

to those of the calyx, and alternating with them, in addition to which they are usually coloured. If the corolla is present, a plant is said to be Dichlamydeous, and much importance is attached to this peculiarity; more, we think, than it deserves. It separates plants having much natural affinity, as Euphorbiaceæ, far from Rhamnaceæ, Amarantaceæ widely from Illecebraceæ, and it is also one to which there are many exceptions. This is, however, not the case with monopetalous dicotyledons, Primulaceæ and Oleaceæ being almost the only instances of orders among those which are truly monopetalous, containing apetalous genera. The difference between a monopetalous and a polypetalous corolla is this, that in the one the leaves out of which the corolla is formed are distinct, and in the other united. Great value is attached to this, and it is in fact a difference of first-rate importance: thus, all Ranunculaceæ, Rosaceæ, Brassicaceæ, Lamiaceæ, Scrophulariaceæ, and Bignoniaceæ are equally, without exception, monopetalous: but in the polypetalous orders of Crassulaceæ, Rutaceæ, Polygalaceæ, Ternströmiaceæ, &c., there are monopetalous genera.—The æstivation of the corolla rarely furnishes characters connected with the natural properties of plants; nevertheless, Asteraceæ are essentially distinguished by their valvate, and Asclepiadaceæ and Apocynaceæ by their contorted æstivation, an exception to the one existing only in the genus Leptadenia, and to the other in Gardneria. The æstivation of both calyx and corolla has as yet received too little attention for its value to be judged of generally.—The regularity or irregularity of the corolla is most commonly important: thus, Orchidaceæ, Polygalaceæ, Bignoniaceæ, Fumariaceæ, are irregular without exception; the regular corolla of Braginaceæ will almost distinguish them from Lamiaceæ, which have frequently an irregular one; yet Echium in Boraginaceæ is irregular, and Caprifoliaceæ exhibit all the gradations from a corolla of the most irregular form to one of the most perfect symmetry. In Asterales both are found continually in the same; in Lobeliaceæ, which may be almost always distinguished from Campanulaceæ by their irregularity, become nearly regular in Isotoma.—The venation of the petals is scarcely ever employed for distinction, little being at present known of it. Asterales are distinguished by the peculiar arrangement of the veins of their corolla; and they are always oblique in Hypericaceæ.

From within the corolla arise the Sexes. From the manner in which these are composed, good characters may sometimes be derived, but more frequently no characters at all. Thus, Xanthoxylaceæ are known from Rutaceæ by their unisexual flowers; all Euphorbiaceæ, Begoniaceæ, Pinaceæ, Myricaceæ, are unisexual. But Vitaceæ, Graminaceæ, Cyperaceæ, Chenopodiaceæ, Apiaceæ, and even Ranunculaceæ, contain hermaphrodite and diclinous genera; and it is familiar to every one, that flowers of all these kinds (that is, male, female, and hermaphrodite) stand side by side in Asterales.

The stamens either arise immediately from below the ovary, having no adhesion to the calyx, when they are said to be hypogynous, or they contract an adhesion of greater or smaller extent with either the calyx or corolla, when they become perigynous, or, finally, they appear to proceed from the apex of an inferior ovary, in which case they are named epigynous; but it is usually now understood that all stamens take their origin from below the ovary; and if this opinion be well founded, there will be no material difference between those which are perigynous and those which are epigynous; and these two modifications are accordingly confounded together by most modern botanists. A. Brongniart, however, conceives epigynous stamens to be essentially distinct from perigynous, founding his opinion upon the genus Raspailia, which has a superior ovary, from the top of which arise the stamens; but it is possible perhaps to explain this apparent anomaly. To the difference between perigynous and hypogynous stamens the French school attaches the greatest value, not being willing to admit any genus with hypogynous stamens into an order with perigynous ones, and *vice versâ*; and there is somewhere an observation, that of such primary importance is this distinction, that while poisonous orders are to be known by their stamens being hypogynous, all in which they are perigynous are wholesome. Setting aside, however, this hypothesis, which has not the general application that has been ascribed to it, there is no doubt that insertion of stamens does very often go

along with essential differences of other kinds; for example, it distinguishes with precision Rosaceæ from Ranunculaceæ, Violaceæ from Passifloraceæ, Reaumuriaceæ from Nitrariaceæ, Aurantiaceæ from Burseraceæ. But on the other hand, there is not only frequently, as may well be supposed, so slight a degree of adhesion between the stamens and calyx as to render it difficult to say whether the former are perigynous or hypogynous, as in Tamaricaceæ, and many others; but there are orders which do really exhibit instances of both modes. Thus Eschscholtzia has decidedly perigynous stamens, and yet it is a genus of Papaveraceæ, the character of which is to have them hypogynous; and all kinds of gradations, from the one form to the other, are observable in Saxifragaceæ. The stamens of Macrostylis, among the hypogynous order Rutaceæ, are manifestly perigynous. In Geraniaceæ, the genus Geranium has the stamens hypogynous, and Pelargonium perigynous. Alsinaceæ are arranged among genera with hypogynous stamens, yet some of them (Larbrea and Adenarium) are perigynous; in Illecebraceæ, part of the genera are perigynous, and part hypogynous. — The manner in which the stamens cohere is sometimes an indication of affinity; for instance, they are monadelphous in Malvaceæ and Meliaceæ, diadelphous in great numbers of Fabaceæ, polyadelphous in Hypericaceæ; but more commonly this character is unimportant, as in Malvaceæ themselves, which have sometimes distinct stamens; Fabaceæ, which have very often such; and Ternströmiaceæ, which have both united and disunited ones.—It not unfrequently occurs, that the conversion of the petals into stamens takes place imperfectly, in which case a part of the stamens is said to be sterile, and this is sometimes a useful character for detecting affinities. Thus, in many Buttnerieæ, one-fifth are sterile and petaloid, in Francoaceæ every other one, in Aquilariaceæ two-thirds, in Bignoniaceæ the uppermost of five is rudimentary.—A peculiarity of a similar nature is the want of symmetry which sometimes exists between the petals or sepals, and stamens. Supposing the flower to be formed without abortion of any kind, and by regular alternation of metamorphoses, as is usually the case, the petals will be always some multiple of the sepals, and the stamens of the petals; and of course any irregularity in this respect will destroy the supposed symmetry. This is often a point of much importance to observe; for example, in Boraginaceæ, the stamens are always equal to the segments of the corolla, and the flowers of that order are consequently symmetrical; in Lamiaceæ, on the contrary, one at least of the stamens is constantly missing, and the flowers are therefore regularly unsymmetrical, a character by which these orders may be constantly known, when the form of their corolla will not distinguish them. In Phytolaccaceæ there is a constant tendency to a want of symmetry; and this is one of the characters by which that order is known from Chenopodiaceæ.

That part of the stamen which contains the fertilizing matter of the anther, is a case usually consisting of two parallel or slightly diverging cells, containing pollen, and opening by a longitudinal fissure; but from this plan many deviations take place, which are of value in determining affinities. Thus, all Malvaceæ, properly so called, and Epacridaceæ, have but one cell; in Lauraceæ and Berberaceæ, the valves are hinged by their upper margin; in Ericaceæ the pollen is emitted by pores; in Melastomaceæ the same takes place, along with a peculiar conformation of the lower part of the anther; in Hamamelaceæ, dehiscence is effected by the falling off of the face of the anthers; but in Solanaceæ, the genera of which have usually their anthers bursting longitudinally, the genus Solanum itself opens by pores.—The mode in which the anther is united with the filament is sometimes taken into account, as in Anonaceæ, Nymphæaceæ, Humiriaceæ, and Araceæ, or Typhaceæ, in which they are always adnate; and Graminaceæ, in which they are as regularly versatile. But this modification appears of no great moment, nor indeed does any peculiarity of the connective, all kinds of forms of which are found in Lamiaceæ; and even in the small order of Penæaceæ we have anthers with the connective both excessively fleshy, and in the ordinary state.

Pollen rarely affords any marks by which affinities are to be traced. The most remarkable deviations from its usual nature exist in Asclepiadaceæ and Orchidaceæ; the former having it always in a state of concretion, resem-

bling wax, by which they are known from Apocynaceæ, and the latter having it frequently so, but also containing numerous genera, the pollen of which is scarcely distinguishable from its ordinary powdery state.

Immediately between the stamens and the ovary is sometimes found a fleshy ring or fleshy glands, called a Disk, and supposed for very good reasons to represent an inner row of imperfectly developed stamens. The presence of this disk is constant in Apiaceæ, Asterales, Lamiaceæ, Boraginaceæ, and Rosaceæ, while its abscnee is equally universal in others. It is not, however, much used as a principal mark of distinction, its real value not having been yet ascertained. There are some curious modifications of it in Rhamnaeeæ and Meliaceæ. It is a remarkable fact, that in Gentianaceæ and their allies, which have the pericarpial leaves right and left with respect to the common axis of inflorescence, it is never truly present; while in Scrophulariaceæ and their allies, the pericarpial leaves of which are anterior and posterior, it is generally present in one shape or other.

The last modification of leaves in the fructification consists in their conversion into what is called the female organ, or ovary; that is to say into the case which contains the young seeds or ovules. Now that the structure of this part is well understood, we know that an ovary cither consists of one or several connected pericarpial leaves, callcd carpels, arranged around a common axis, or of several combined into a single body. Upon this difference the distinction depends of what are called apocarpous ovaries, or those of which the carpels are distinct; and syncarpous, or those of which the carpels are compactly combined. These differences appear of much importance, and subject to as few exceptions as any modifications that botanists make use of. Thus Berberaceæ are distinguished from Papaveraceæ, Nelumbiaceæ from Nymphæaceæ, Amaryllidaceæ from Burseraceæ, Boraginaceæ from Ehretiaceæ, and the like. But at the same time it will be seen, that cases exist of both forms being found in the same natural order, as Xanthoxylaceæ. This, however, is rare.—The cohesion of the ovary with the calyx, or its separation from it, has been already treated of in speaking of the calyx.—An ovary may be either one-celled, in consequence of its consisting of a single carpel, in which case it will belong to the apocarpous division; or it may consist of several carpels strictly cohering, and therefore syncarpous, but nevertheless one-celled, in consequence of the obliteration of the dissepiment. Peculiarities of this latter nature are almost always of ordinal importance, *at least if the placentæ are parietal;* for instance, the latter is the structure of Papaveraceæ, Homaliaceæ, Flacourtiaceæ, Cucurbitaceæ, Papayaceæ, and Violaceæ, to which there is no exception; but Alsinaceæ and Bruniaceæ, the usual structure of which is to be one-celled, have the placentæ in the centre; and in both these orders there are genera, the ovary of which contains several cells.—Another point that deserves particular attention is the relation borne to the axis of inflorescence by the pericarpial leaves, of which an ovary is formed. What the exact value of this character may be is not yet known; but it seems that Gentianaceæ and their allies have their pericarpial leaves right and left of the axis, while Scrophulariaceæ and their allies have the pericarpial leaves anterior and posterior, with respect to the axis. Rosaceæ and Fabaceæ differ in a nearly similar way.—Conncctcd with the apocarpous or syncarpous state of the ovary is the union or separation of the styles, which therefore scarcely require distinct mention. It is as well, however, to remark, that the separation of styles is commonly a sign of the apocarpous state of the ovary, providcd the latter is not very apparent otherwise; and the cohesion of the styles is constantly an evidence of the contrary; and in this view the Elder and Hydrangea may be justifiably separated from Caprifoliaceæ.—The recoptacle or growing point round which the carpels are disposed is commonly so minute as to interpose but little matter between the bases of the carpels which stand nearly parallel with each other. But this part occasionally takes on an extraordinary developement, becoming fleshy, and either separating the carpels entirely from each other, as in the Strawberry and in Ochna, or causing them to diverge at their base, to which they adhere by the points of their ovary. The term *gynobase* has been inventcd by the French to denote this kind of receptacle, and strictly speaking it

ought to be applied to all cases of an enlarged receptacle. But in practice nothing is considered a gynobase, on which more than one row of carpels is arranged. This character, indicated in the fruit by the presence of a central woody column to which the carpels partially adhere, is sometimes of so much value as to form the cementing character of several well-marked and very distinct orders. It has given rise to a group called Gynobaseosæ among Polypetalous Exogens.

The stigma seldom offers any good characters. In some cases, however, advantage is taken of it, as in Linaceæ, the capitate stigmas of which distinguish them from Alsinaceæ, where they occupy the whole inner face of the styles; and in Goodeniaceæ, Scævolaceæ, and Brunoniaceæ, there is a peculiar membranous appendage enveloping the stigma, and called an indusium, which distinguishes those orders from all others.

The number of the ovules (that is to say, whether they are definite or indefinite) is frequently an important difference, as, for example, between Campanulaceæ and Asterales, Goodeniacæ and Scævolaceæ; but while considerable value usually attaches to this, it must not be forgotten that there are exceptions to it in several instances, especially in Caprifoliaceæ, Fumarieæ, and Brassicaceæ.—The position of the ovules is much more essential than their number, and may be considered as one of the most valuable forms of structure that can be taken into account. It is uniform in Asterales, Valerianaceæ, Apiaceæ, and others; but in Sanguisorbeæ, Pedaliaceæ, and Styraceæ, both erect and suspended ovules co-exist; this union of the two positions occurs in a more remarkable degree in Penæaceæ; and among Violaceæ, the genus Conohoria offers, according to A. St. Hilaire, *Pl. Usuelles*, No. 10, an instance of three kinds of direction in as many species; in C. Lobolobo, the ovules are ascending; in C. castaneæfolia, they are suspended; and in C. Rinorea, one is suspended, one ascending, and the intermediate peritropal, or at right angles with the placenta.—The situation of the foramen of the ovule is a circumstance that should always be taken into account, because it indicates with certainty the future position of the radicle, which it is of importance to ascertain, but which will be more properly spoken of in considering the value of distinctions drawn from that source.

The ripened ovary is the fruit. The differences in its structure are of the same nature as those of the ovary, and need not be repeated. Its texture and mode of dehiscence are the principal sources of distinction, but they perhaps deserve as little attention as any of which botanists make use. It is true that the fruit of all Grossulaceæ is baccate, of all Lamiaceæ indehiscent, and of all Primulaceæ capsular; but Marcgraaviaceæ, Melastomaceæ, Myrtaceæ, Ranunculaceæ, and Rosaceæ, with a crowd of other orders, contain both baccate and capsular, dehiscent and indehiscent genera.

The characters obtained from the position of the seed are of the same value as those from the position of the ovule; in addition to which, the peculiarities of the testa are made use of. —In some Monocotyledonous orders, as Liliaceæ and Smilaceæ, the texture has been employed as a mark of distinction, but with little reason, the soft thin testa of Smilax being found in genuine Liliaceæ of the Asphodeleous section; it is indeed rather surprising that botanists should have ever thought of having recourse to a distinction so wholly unconnected with function or typical organization.—The seed being winged or otherwise, distinguishes Meliaceæ from Cedrelaceæ, and the presence of a fungous swelling about the hilum is a good characteristic of Polygalaceæ.

The substance that surrounds the embryo is the Albumen; its absence or presence constitutes a valuable mark of distinction. There can be no doubt that when it exceeds the bulk of the embryo very considerably, as in Ranunculaceæ, Papaveraceæ, Apiaceæ, Grasses, and the like, it is of such importance, that no plant destitute of albumen is likely to be found appertaining to such orders, for in such cases it is to be supposed that it contributes essentially to the nutrition of the embryo when first germinating; and is in reality indispensable to it. But on the other hand, it is much to be doubted whether its presence or absence deserves much attention in orders which are called by German botanists subalbuminous, where it is a mere residuum,—that is to say, where the embryo and albumen are of nearly

equal bulk; for it should be remembered, that it always exists in seeds at some period of their existence, and that its remains may very well be expected to be found in almost any seeds; thus, in fact, both albuminous and exalbuminous seeds are found in Proteaceæ (Brown in *Linn. Trans.* x. 36); even in Rosaceæ, which are as free from remains of albumen as any order, it is said to be distinctly present in Neillia, and in other orders traces of it are to be seen adhering to the inner membrane of the testa.—The texture of the albumen is frequently consulted with advantage; in all Cinchonaceæ it is horny or fleshy; Euphorbiaceæ, oily; Grasses, Polygonaceæ, Chenopodiaceæ, mealy; in Anonaceæ, it is ruminated, &c.; but among Apocynaceæ, which have solid albumen, it is ruminated in Alyxia.

The direction of the Embryo within the testa, which is indicated in the ovule by the foramen, is one of the very few characters to which we know of no exceptions; and if it were a less obscure point of structure, it would be consequently one of the most useful. For example, in all Cistaceæ, Urticaceæ, and Polygonaceæ, the radicle is not turned towards the hilum, as in other tribes, but takes an opposite direction; and these orders are distinguished from their allies by this, better than by any other known character.

The number of Cotyledons is one of the means of distinguishing the great natural divisions called Monocotyledons, Dicotyledons, and Acotyledons. There are, however, plants among Monocotyledons with two cotyledons, as the common Wheat; and among Dicotyledons with only one, as Penæa and some Myrtaceæ; or even none, as Cuscuta and Utricularia; or several, as Schizopetalon in Brassicaceæ, Amsinckia in Boraginaceæ, Ceratophylleæ, and most Pinaceæ.—The position of the embryo with respect to the albumen is of variable importance; in all Grasses it is lateral, in Cyperaceæ it is enclosed within the base of the albumen, and thus it furnishes an absolute distinction between those two important orders. But among Polygonaceæ, Rheum has it in the centre of its albumen, and Rumex on one side.—Differences in the manner in which the embryo is folded up are always of great consequence; because, although they may vary in particular natural orders, yet they are in such cases characteristic of subordinate divisions in the orders. For instance, both a straight embryo and one with the radicle bent down upon the cotyledons occur in Fabaceæ; but the first marks the Papilionaceous division, and the last the two groups of Cæsalpinieæ and Mimoseæ. Brassicaceæ, Capparidaceæ, Resedaceæ, Menispermaceæ, &c. have a curved embryo; Malvaceæ and Convolvulaceæ a crumpled one; but in Silenaceæ we have both a straight and annular one, and in Chenopodiaceæ and others equal uncertainty exists.

The only remaining character of vegetation which it is necessary to notice is a singular and very uncommon one, which distinguishes a few small families of plants. This consists in the presence of the remains of the Amnios around the embryo in its perfect state: the Amnios always surrounds the embryo in an early state, but is most commonly absorbed before the formation of the embryo is completed; but in Saururaceæ, Piperaceæ, and Nymphæaceæ, it remains around the embryo in the form of a sac, which was mistaken by Richard, who did not understand its nature, for a peculiar appendage of the embryo, or rather for a particular form of the radicle.

Chapter VIII.

Of the practical application of the foregoing principles.

If the foregoing principles have been rightly understood, their application will lead to the formation of a Natural arrangement of all known plants; by which we must be understood to mean an arrangement wherein all the groups will consist of species more nearly related to each other than to any thing else; where every genus, alliance, group, &c. will consist of species, &c., in the closest affinity with each other.

If it could be shown that in all cases of affinity one character would be stronger than all others, another result would be that there could be but one Natural System, and that, however long botanists might be in discovering it, they must at last and inevitably arrive at *the* one system and no other; and this proposition is actually maintained by some naturalists. But there are probably no cases in which there is a preponderating affinity in one direction and

one only: on the contrary, the equal affinities of plants are numerous and complicated, and in many respects it is impossible to demonstrate what their relative value really is; consequently, instead of one certain and inevitable result, instead of one fixed and immutable system to which the application of certain admitted principles must of necessity lead, several systems have been and may still be devised, all of which are natural and yet all different: not, however, different in their great leading features, but in their subordinate details. The great leading features of a system consist in the orders or first groups of genera, and in the classes or last groups of orders. About these there can be only one opinion, whenever all the data requisite for certainty shall have been collected; whatever differences in opinion concerning them may now exist, arise from the absence of many important data. But as to the arrangement of the genera in the orders, or of the orders in the classes, that always has been and ever will be a matter about which opinion will vary according as new facts are made known, or as persons take different views of the same facts. However wrong, therefore, Fries may be in asserting that there is no such thing as an artificial system, he is not far wrong in asserting that there is no absolutely natural system, because all systems, as far as their arrangement is concerned, are necessarily artificial; and a system which to-day is called Natural, may to-morrow become, by the accession of new ideas, artificial; as that of Tournefort, &c.

Nevertheless, it is very possible that particular modes of arrangement may be less natural than others; that is to say, may be less calculated to keep together corresponding assemblages; and that others may be perfectly natural in their classes and orders, but purely artificial in their intermediate details. Thus, Jussieu, in employing the single and absolute character of hypogynous, perigynous, and epigynous insertion of the stamens, rendered all his system artificial except the classes and orders; and De Candolle, in adhering to the same principle, destroyed in a great degree the value of what he calls his cohorts.

It may be, and indeed has been urged, that as a lineal arrangement is the only one that can be adopted in books, and as this is altogether incapable of indicating the nature of a system which "has for its very aim to interweave all the objects of nature in a close and compact web of mutual dependence," so it is really of little importance whether the intermediate grouping of plants is more or less artificial, as it must necessarily be so in some degree. But this we think is a great and very important mistake. It surely does not follow that because our finite means are incapable of explaining altogether what is infinite, that therefore we should not make the best use of the means of explanation that we actually possess; and yet this is the same thing as to say that, because a part of the most natural arrangement must necessarily be in some measure artificial, it does not matter how artificial it all is. It might as well be said, that because additions to the amount of our knowledge of species are daily accruing, and because so long as these additions are taking place our ideas of systematic arrangements will be changing, therefore it is not worth occupying ourselves with systematic arrangements at all, until every existing species has become correctly known. To admit such doctrine as this would be to give up the search for perfection in any thing; no one can hope to attain perfection; and there can be no reasonable doubt, that new points of view and continual improvements of what has gone before will be occurring to those who shall live a thousand years hence.

The true method of proceeding, with regard to the principles treated of in previous chapters, is to arrange the assemblages intermediate between the highest and lowest combinations in a manner *as little artificial as existing circumstances will allow.*

So little, however, has this been attended to, that in speaking of the Natural System of Botany as a whole, we shall be obliged to pass by the plans of Jussieu and De Candolle, and to take for the basis of the observations in the succeeding chapter, some one of those recent systems, which, although founded upon the writings of those two distinguished botanists, in the same manner as theirs are upon the discoveries and improvements of Ray and Tournefort, differ from them essentially in the arrangement of what we have designated as the intermediate assemblages. We are the more induced to take this course, because we have no space in this essay to notice all the plans that have been

proposed for a Natural System. Partly for a similar reason, and secondly because it is the most recent, we select for the text of the succeeding chapter the system of Professor Lindley, imperfect as he admits it to be, and great as are the changes and improvements that he feels it must require before it can be at all established.

Chapter IX.

Of Natural Systems.

A Natural System is a classification of species according to their respective affinities, so that those shall be placed next each other which correspond in the greatest number of particulars, and those be stationed most remotely that have the fewest points of agreement. It is not in our power to put this idea into practice altogether; we are therefore obliged to add, that those also are Natural Systems in which the principle is recognized as essential and fundamental.

In classifying either the vegetable or animal kingdoms, two diametrically opposite methods may be pursued, both of which shall be strictly natural. We may either proceed from the most imperfect forms of organization, or correctly speaking the most simple, for every thing is equally perfect after its kind, to the most complicated; or from the most complicated to the most simple. The first is the course pursued by Jussieu; the latter is that of Ray and De Candolle. It may at first sight appear to be of little moment which of these methods is pursued; but we agree with Fries and De Candolle, that in reality there is a material difference between these plans. "To me," the former says, "it appears most advisable to commence with that which is most perfect, most completely developed, and therefore most easily understood; and thence to descend to forms of a more imperfect kind, and therefore of a more doubtful nature. The half-developed portions of the lower forms of the creation would never be understood, if they were not more completely developed in the higher forms. This is the path which is pointed out both by experience and common sense; the idea of a seed is not derived from an Uredo, nor that of a vegetable from an Erineum; but the reverse. This is especially true of those lower spheres which bring up the rear: the last point of simplicity will never be attained, and will never be determined; although our microscopes are daily extending our views, the poles of vitality will never be reached. It is better, therefore, to set out from a *certain* point (the centre) than from an *uncertain* point (the circumference), which may be extended to infinity. So it is more wise, in studying Man, to take our notions of humanity from those in whom it exists in the highest degree of perfection, rather than to search over-curiously for those whose intellect is approximating to that of animals."

To this it may be added, that we really know much less of simple than of complicated forms, and it is contrary to all the rules of logic to begin by objects that are little known in order to understand those which are better known. We should form an odd notion of a man from a monad, but we should be able to understand a monad from our knowledge of a man.

Taking then this method of commencing our inquiry—we find that the most complete cases of structure that can be discovered are those where, in addition to stems and leaves wherewith to grow, and seed by which to multiply, there is a peculiar and complicated sexual apparatus of stamens and pistils by the action of which the seeds are fertilized. These, the most perfect forms of plants, have also other characters in common, all of which indicate a higher grade of organization; they have flowers; they are anatomically composed of cellular tissue and spiral vessels, and the seeds which they produce have two definite points of growth, of which one becomes invariably a stem, and the other a root. Those plants, on the contrary, which have no sexual apparatus, are also destitute of flowers; they have no true spiral vessels in their anatomical structure, but grow chiefly by aid of their cellular tissue, and the seeds which they produce have no definite points of growth, but produce stem or root indifferently from any point of their surface; their seed is therefore different from true seed, and is called a spore or sporule. This first examination shows then that we have two sorts of plants differing essentially in the degree of their developement, in the manner in which they are multiplied, in the means by which their vital actions are performed, and consequently in their whole mode of existence. These may be provisionally set down thus:—

Sexual. — Flowering. — Vascular. — Seminiferous.

Asexual. — Flowerless.—Cellular. — Sporiferous.

Viewed in another way, namely, with reference to their manner of growth, plants again divide into two wholly different series; in one of which the trunk every year after its first formation either actually increases in diameter or adds new matter to its solid contents; and this series comprehends two parallel and essentially dissimilar types, in which one adds its new matter to the outside of its wood near the circumference of the stem, and the other to the inside of its wood near the centre; the first are Exogens, the latter Endogens. In the other series the stem, when once formed, neither increases in diameter nor adds new matter to its solid contents; but merely lengthens at its extremity; such plants are Acrogens. This is another set of fundamental peculiarities which will necessarily regulate some of the most important vital actions of the species comprehended under them. Upon comparing these series with the first class of peculiarities, it appears that Exogens and Endogens are uniformly Sexual, &c.; and that Acrogens are as uniformly Asexual; hence we have three great fundamental groups instead of two—namely,

1. Sexual. — Flowering. — Vascular. —Seminiferous.—Exogens.

2. Sexual. — Flowering. — Vascular. —Seminiferous.—Endogens.

3. Asexual.—Flowerless. — Cellular. —Sporiferous.—Acrogens.

Each of these three groups has other peculiarities, which mark it in one way or another. Exogens have an embryo with two cotyledons (Dicotyledons); in germination, their young root springs directly from the apex of the radicle (Exorhizal); their leaves have netted veins, if any; the parts of their flowers are usually arranged upon a quinary or quaternary plan. Endogens have an embryo with one cotyledon (Monocotyledons); in germination, their young root springs from within the point of the radicle (Endorhizal); their leaves have simple parallel veins, if any; the parts of their flower are usually arranged upon a ternary plan. Acrogens have no embryo, and consequently no cotyledons (Acotyledons); in germination, their young root springs from any part of the spore (Heterorhizal); their leaves have forked veins, if any; flowers they have none. These various circumstances place the distinctions between the three fundamental classes in a still stronger light; and serve to show that when plants differ in one very essential character, they also differ in others, the number of which will be in proportion to the importance of the first character. If we again combine all these equivalent and corresponding characters in a rather different manner, they will finally offer the following contrast.

Exogens, or Dicotyledons,	have sexes, spiral vessels, seeds, 4-5-nary flowers, netted-veined leaves, exorhizal germination.
Endogens, or Monocotyledons	have sexes, spiral vessels, seeds, 3-nary flowers, parallel-veined leaves, endorhizal germination.
Acrogens, or Acotyledons,	have no sexes, no spiral vessels, spores, no flowers, forked veined leaves, heterorhizal germination.

These distinctions speak so directly to our senses, that no person when he has once understood them would be at all likely to call them in doubt. To know that the forest trees and bushes, and the common herbs of the field, are Exogens; that Palms, and Lilies, and Rushes, and Grasses, are Endogens; and that Acrogens answer to Ferns and Mosses, and Lichens and Fungi, is quite sufficient to impress the mind with a general, if not a very distinct perception, that while these groups called classes are totally different from each other, they have great and obvious marks of correspondence among themselves.

There are many who believe that these are the only classes into which the vegetable kingdom is capable of being divided. But others add two more. From Exogens are struck off those curious plants which, having sexes, nevertheless have them in a singularly incomplete state; their young ovules being fertilized by direct contact with the pollen, instead of through the intervention of a style and stigma; in these plants, moreover, the vascular system is more imperfect than in other Exogens, and their leaves, if veined, have either the forked veins of Acrogens, or the parallel veins of Endogens. They may therefore be reasonably

looked upon as a fourth class, and are called GYMNOSPERMS.

Finally there are certain plants which, to an appearance like that of Fungi, and an almost total absence of spiral vessels, add the flowers of Endogens, and the spores of Acrogens, have sexes, and the result of their sexuality is not an embryo, but a homogeneous reproductive body, with neither radicle nor cotyledons. They are supposed to be, in all cases, parasitical on roots, and hence have gained the name of RHIZANTHS; they constitute a fifth class.

These five classes, viz.,

1. Exogens,
2. Gymnosperms,
3. Endogens,
4. Rhizanths,
5. Acrogens,

are admitted by Professor Lindley. Subordinate to them are numerous groups, each divided into alliances, under which the orders are finally arranged.

Of the genera we can of course give no account in a short treatise like this; but such an abstract as the following, of the characters of the higher combinations, is necessary, to render the foregoing discussion either useful or intelligible. For a full explanation of the more special reasons upon which the system is founded, the reader is referred to the work itself from which these characters are abridged.*

* A Natural System of Botany; or a Systematic View of the Organization, Natural Affinities, and Geographical Distribution of the Vegetable Kingdom. By John Lindley, Ph. D. &c., Second Edition. London. 1836.

THE NATURAL ORDERS OF PLANTS.

Class I.—EXOGENS OR DICOTYLEDONS.

Elementary organs consisting of both cellular and vascular tissue, a portion of the latter being elastic spiral vessels. Trunk increasing by an annual deposit of new wood and cortical matter between the wood and bark. Leaves articulated with the stem, their veins reticulated. Propagation effected by stamens and pistils. Ovules in a pericarp, embryo with two or more opposite cotyledons.

Sub-class I.—POLYPETALÆ.

Floral envelopes consisting of both calyx and corolla; the latter composed of distinct petals.

Group 1.—Albuminosae

The albumen very considerably larger than the embryo, and forming the great mass of seed.

Alliance 1.—Ranales. *Herbaceous, rarely woody, plants; either with the carpels more or less distinct, or if that is not the case, with parietal placentæ.*

Order 1.—*Ranunculaceæ.* Sepals 3-6, deciduous. Petals 3-15. Stamens hypogynous, anthers adnate. Carpels numerous, or united into a single pistil. Seeds either erect or pendulous. Herbs or shrubs. Leaves with the petiole dilated.

Sub-order Podophylleæ. Sepals 3. Petals in two or three rows. Stamens hypogynous; anthers linear or oval. Torus not enlarged. Fruit 1-celled. Seeds sometimes having an aril. Herbaceous plants. Leaves lobed.

Order 2.—*Papaveraceæ.* Sepals 2. Petals either 4 or some multiple of that number. Stamens hypogynous, generally numerous. Fruit 1-celled with parietal placentæ. Seeds numerous. Herbaceous plants or shrubs with a milky juice. Leaves alternate.

Sub-order—Fumarieæ. Sepals 2. Petals 4; parallel; the outer one or both saccate at the base. Stamens 6, in 2 parcels. Herbaceous plants with brittle stems and a watery juice.

Order 3.—*Nymphæaceæ.* Sepals and petals imbricated, passing gradually into each other. Stamens numerous, inserted above the petals into the disk; filaments petaloid; disk large, fleshy. Fruit many-celled. Seeds very numerous, attached to spongy dissepiments. Embryo on the outside of the base of the

albumen, in a bag. Herbs with peltate or cordate fleshy leaves, growing in quiet water.

Sub-order—Hydropeltideæ. Sepals 3 or 4. Petals 3 or 4. Stamens definite or indefinite. Ovaries 2 or more; fruit indehiscent. Seeds definite. Aquatic plants with floating leaves.

Order 4.—*Nelumbiaceæ.* Sepals 4 or 5. Petals numerous. Stamens numerous. Disk fleshy, enclosing in hollows of its substanee the ovaries, which are monospermous. Nuts numerous, half buried in the disk. Herbs with peltate, floating leaves.

Allianee 2.—Anonales. *Woody plants in all cases, often trees with the fruit composed of distinct carpels, which occasionally grow together into a solid mass. The valves of the anthers separating by a perpendicular line.*

Order 5.—*Cephalotaceæ.* Calyx coloured, six parted, with a valvate æstivation. Corolla 0. Stamens 12. Carpels 6, one-seeded; ovule erect. A stemless herb with operculate pitchers. Flowers small.

Order 6.—*Myristicaceæ.* Flowers unisexual. Calyx trifid. Ovary superior, with a single ereet ovule. Fruit 2-valved. Seed enveloped in a many-parted aril; albumen ruminate. Tropical trees, often yielding a red juiee.

Order 7.—*Magnoliaceæ.* Sepals 3-6. Petals 3-27. Stamens indefinite. Carpels numerous, distinet or consolidated. Trees or shrubs with convolute stipules. Flowers large, solitary.

Order 8.—*Winteraceæ.* Sepals 2-6. Petals 2-30. Stamens hypogynous. Ovaries 1-celled with suspended or erect ovules. Fruit consisting of a single row of carpels. Seeds with or without aril. Shrubs or small trees. Leaves alternate, dotted, with convolute deciduous stipules. Flowers often brown.

Order 9.—*Anonaceæ.* Sepals 3-4. Petals 6, coriaeeous, with a valvular æstivation. Stamens indefinite; filaments angular. Ovaries numerous. Fruit succulent or dry, with the earpels 1 or many-seeded, separate or consolidate. Albumen ruminate. Trees or shrubs. Leaves without stipules. Flowers axillary.

Sub-order—Schizandreæ. Trailing plants with unisexual flowers, monadelphous stamens, and solid albumen.

Order 10.—*Dilleniaceæ.* Sepals 5; 2 exterior, 3 interior. Petals 5. Stamens indefinite. Ovaries definite. Carpels baeeate or 2-valved. Seeds surrounded by a pulpy aril. Embryo in solid fleshy albumen. Trees, shrubs or under-shrubs, rarely herbaceous, leaves without stipules. Flowers often yellow.

Alliance 3.—Umbellales. *Flowers usually disposed in umbels. Calyx superior. Disk epigynous, very thick, in two or more pieces. Carpels always* 1-*seeded. Stems usually hollow.*

Order 11.—*Apiaceæ* or *Umbelliferæ.* Calyx entire or 5-toothed. Petals 5, usually inflexed at the point. Stamens 5, alternate with the petals. Ovary 2-celled. Fruit eonsisting of 2 earpels, separable from a eommon axis. Seed pendulous. Herbaecous plants with fistular stems. Flowers in umbels.

Order 12.—*Araliaceæ.* Calyx entire or toothed. Petals 5-10. Stamens equal to the petals or twice as many, arising from without an epigynous disk. Ovary with more eells than two. Fruit sueeulent or dry, consisting of several 1-seeded cells. Seeds pendulous. Trees, shrubs, or herbaceous plants, with the habit of Apiaceæ.

Alliance 4.—Grossales. *Flowers never arranged in umbels. Calyx superior, epigynous. Disk, if present, not in several pieces. Carpels usually many-seeded, with the seeds distinct from the pericarp. Stem solid.*

Order 13.—*Grossulaceæ.* Calyx 4- or 5-parted, regular. Petals 5, minute. Stamens very short. Ovary 1-celled with 2 parictal plaeentæ. Berry 1-celled.

Order 14.—*Escalloniaceæ.* Calyx 5-toothed, petals forming a tube, but finally separating; æstivation imbricated. Stamens arising from the calyx. Disk conical, epigynous. Ovary 2-celled, with two large polyspermous plaeentæ in the axis; stigma 2-lobed. Fruit capsular, splitting by the separation of the cells at their base. Seeds minute; embryo in oily albumen. Shrubs with alternate, toothed, glandular, exstipulate leaves.

Order 15.—*Bruniaceæ.* Calyx 5-cleft, imbricated. Petals imbricated. Stamens alternate with the petals; anthers turned outward. Ovary half inferior

with from 1 to 3 cells. Ovules suspended, 1-2. Stigma simple. Fruit crowned by the permanent calyx. Seeds sometimes with a short aril. Branched heath-like shrubs. Flowers often capitate.

Alliance 5.—Berberales. *Anthers bursting by recurved valves.*

Order 16.—*Berberaceæ.* Sepals 3-4-6, in a double row. Petals sometimes with an appendage at the base. Stamens equal in number to the petals, and opposite to them; anthers opening elastically with a valve from the bottom to the top. Ovary solitary, 1-celled. Seeds attached to the bottom of the cell, 1, 2, or 3, albumen between fleshy and corneous. Shrubs or herbaceous perennial plants. Leaves alternate, compound, usually without stipules.

Alliance 6.—Pittosporales. *Carpels all combined into a solid ovary, with a single style. Placentæ central. Stamens never epigynous.*

Order 17.—*Vitaceæ.* Calyx small, nearly entire. Petals in æstivation valvate and often inflected at the point; stamens opposite them, inserted upon the disk. Ovary 2-celled; ovules erect, definite. Berry pulpy; albumen hard. Scrambling, climbing shrubs, with tumid separable joints. Leaves with stipules. Flowers small green.

Order 18.—*Pittosporaceæ.* Sepals deciduous, imbricated. Petals hypogynous, imbricated. Stamens 5, hypogynous. Ovary single, many-seeded. Fruit capsular or berried, with many-seeded cells which are sometimes incomplete. Albumen fleshy. Leaves simple, alternate, without stipules.

Order 19.—*Olacaceæ.* Calyx small, finally enlarged. Petals valvate, separate or cohering in pairs. Stamens definite, part fertile, part sterile, hypogynous. Ovary 1-celled, with 3 ovules pendulous from a central column. Fruit indehiscent, frequently surrounded by the enlarged calyx, 1-seeded. Seed pendulous. Trees or shrubs often spiny. Leaves alternate, entire, without stipules.

Order 20.—*Francoaceæ.* Calyx 4-cleft. Petals 4. Stamens sub-hypogynous, four times as numerous as the petals, alternately rudimentary. Ovary with 4 cells; ovules numerous. Capsule 4-valved. Seeds numerous, minute. Herbaceous plants, with lobed or pinnated leaves, without stipules. Petals persistent.

Order 21.—*Sarraceniaceæ.* Sepals 5, imbricate. Petals 5, unguiculate, concave. Stamens indefinite, hypogynous. Ovary 5-celled; stigma very large, peltate. Capsule crowned by the stigma. Seeds very numerous, minute. Herbaceous perennial plants, living in bogs. Leaves with a hollow urn-shaped petiole. Scapes bearing one large flower.

Group 2.—Epigynosae.

Ovary inferior, usually having an epigynous disk. Seeds not having a disproportionate quantity of albumen.

Alliance 1.—Onagrales. *Æstivation not valvate. Placentæ central. Every part of the flower some regular multiple of two. In most cases herbaceous plants.*

Order 22.—*Onagraceæ.* Calyx tubular, 4-lobed, valvate. Petals regular, with a twisted æstivation. Stamens four or eight, inserted into the calyx. Stigma 4-lobed. Fruit many-seeded, with 4 cells. Seeds without albumen. Herbaceous plants or shrubs. Leaves alternate or opposite.

Sub-order—Circæeæ. Stamens 2. Disk large, cup-shaped. Ovary 2-celled. Ovules solitary, erect.

Sub-order—Halorageæ. Calyx minute. Petals minute or 0. Stamens often fewer than the lobes of calyx. Ovules solitary, pendulous.

Sub-order—Hydrocaryes. Calyx 4-parted. Petals 4. Stamens 4. Ovary 2-celled. Ovules solitary, pendulous. Fruit horned, 1-celled. Seed solitary with very unequal cotyledons. Floating plants.

Alliance 2.—Myrtales. *Æstivation not valvate. Placentæ occupying the centre of the fruit. Parts of the flower not a regular multiple of any number throughout. In most cases shrubby plants or trees.*

Order 23.—*Combretaceæ.* Calyx 4- or 5-lobed, deciduous. Stamens twice as many as the segments of the calyx, or three times as many. Ovary 1-celled, with

from 2 to 4 ovules, hanging from the apex of the cavity. Seed without albumen; cotyledons usually convolute. Trees or shrubs. Leaves without stipules.

Order 24.—*Alangiaceæ.* Calyx campanulate, 5-10-toothed. Petals 5-10, linear, reflexed. Stamens two or four times as numerous as the petals. Drupe 1-celled, bony. Seed inverted; albumen fleshy; cotyledons flat. Large trees. Branches often spiny. Leaves alternate, without stipules, entire, without dots.

Order 25.—*Rhizophoraceæ.* Calyx with the lobes varying from 4 to 13. Petals alternate with the lobes. Stamens twice or thrice their number. Ovary 2-celled, each cell containing two or more pendulous ovules. Fruit indehiscent, crowned by the calyx, 1-celled, 1-seeded. Seed without albumen. Coast trees or shrubs. Leaves opposite, with stipules between the petioles.

Order 26.—*Memecylaceæ.* Calyx 4- or 5-lobed or toothed. Stamens 8-10; anthers incurved. Ovary 2-4, rarely 8-celled; ovules solitary, pendulous. Fruit crowned by the calyx, indehiscent. Seeds without albumen; cotyledons foliaceous, convolute. Shrubs. Leaves opposite without stipules or dots.

Order 27.—*Melastomaceæ.* Calyx cohering with the angles of the ovary. Petals twisted in æstivation; filaments curved downwards in æstivation; anthers long, 2-celled, elongated beyond the insertion of the filament. Ovary with several cells, and indefinite ovules. Pericarp with placentæ attached to a central column. Seeds innumerable. Trees, shrubs, or herbaceous plants. Leaves opposite, with several ribs.

Order 28.—*Myrtaceæ.* Calyx 4- or 5-cleft, sometimes like a cap. Petals quincuncial. Stamens indefinite; anthers ovate, small. Ovary 1-2-4-5-6-celled. Fruit either dry or fleshy. Seeds indefinite; embryo without albumen. Trees or shrubs. Leaves opposite, with transparent dots, and a vein running parallel with their margin.

Sub-order ?—Barringtonieæ. Leaves alternate, stipulate, without dots.

Order 29.—*Lecythidaceæ.* Calyx 2- to 6-leaved, or urceolate. Petals with an imbricated æstivation. Stamens indefinite, epigynous, either cucullate or monadelphous. Ovary 2- to 6-celled; ovules attached to the axis. Fruit woody. Seeds several; embryo without albumen. Large trees, with alternate entire or toothed leaves, with minute stipules, without dots. Flowers large, showy, terminal.

Order 30.—*Philadelphaceæ.* Calyx persistent, having from 4 to 10 divisions. Petals convolute-imbricate. Stamens indefinite. Styles distinct, or consolidated; stigmas several. Capsule with 4 to 10 cells, many seeded. Seeds scobiform; aril loose, membranous. Albumen fleshy. Shrubs. Leaves deciduous, opposite, without dots or stipules. Flowers always white.

Alliance 3.—Cornales. *Æstivation of corolla valvate.*

Order 31.—*Hamamelaceæ.* Calyx in 4 pieces. Petals 4, linear. Stamens 8; 4 being sterile. Ovary 2-celled; ovules solitary, pendulous. Fruit capsular. Embryo in the middle of horny albumen. Shrubs. Leaves alternate with deciduous stipules. Flowers sometimes unisexual.

Order 32.—*Cornaceæ.* Sepals 4. Petals 4, oblong, broad. Stamens 4. Drupe crowned by the calyx, 2-celled. Seeds pendulous, solitary. Albumen fleshy. Trees or shrubs, seldom herbs. Leaves (except in one species) opposite, entire or toothed.

Order 33.—*Loranthaceæ.* Calyx with 2 bracts at the base. Corolla with 3, 4 or 8 petals, more or less united at the base, valvate; stamens opposite to them. Ovary 1-celled; ovule pendulous. Fruit succulent. Seed solitary; embryo cylindrical, longer than the fleshy albumen. Parasitical half shrubby plants. Leaves opposite, without stipules.

Alliance 4.—Cucurbitales. *Placentæ parietal. Flowers neither with a valvate corolla, nor with any other character appertaining to the preceding alliances.*

Order 34.—*Cucurbitaceæ.* Flowers unisexual. Calyx 5-toothed. Corolla 5-parted, scarcely distinguishable from the calyx, with strongly reticulated veins. Stamens 5, either distinct, or cohering in three parcels; anthers sinuous. Ovary with 3 placentæ; stigmas very thick, velvety or fringed. Fruit more or less succulent. Seeds flat, in an aril; embryo flat, with no albumen. Annual or perennial. Stem climbing by tendrils. Leaves palmated, or with palmate ribs, covered with asperities.

Order 35.—*Loasaceæ.* Calyx 5-parted. Petals 5 or 10, cucullate with an inflexed æstivation; the interior often much smaller. Stamens indefinite. Ovary with several placentæ or with 1 free central lobed one. Fruit capsular or succulent. Seeds numerous without aril; embryo in the axis of fleshy albumen. Herbaceous plants, hispid, with pungent hairs. Leaves without stipules.

Order 36.—*Cactaceæ.* Sepals indefinite, confounded with the petals. Stamens indefinite; filaments long, filiform. Ovary with numerous placentæ; stigmas numerous. Fruit succulent. Seeds without albumen. Succulent shrubs, usually destitute of leaves, and with spinous buds.

Order 37.—*Homaliaceæ.* Calyx funnel-shaped, with from 5 to 15 divisions. Petals equal to them in number. Glands in front of the segments of the calyx. Stamens from the base of the petals. Ovary half inferior, 1-celled with numerous ovules; styles from 3 to 5; as many placentæ as styles. Embryo in the middle of fleshy albumen. Trees or shrubs. Leaves alternate, with deciduous stipules.

Alliance 5.—Ficoidales. *Petals narrow and numerous. Placentation not parietal.*

Order 38.—*Mesembryaceæ* or *Ficoideæ.* Sepals definite, succulent. Petals indefinite, linear. Stamens indefinite. Ovary many-celled. Stigmas numerous. Capsule many-celled with a starry dehiscence. Embryo curved or spiral, on the outside of mealy albumen. Succulent shrubs or herbs. Flowers showy, opening only under bright sunshine.

Alliance 6.—Begoniales. *Flowers unisexual. Placentæ central.*

Order 39.—*Begoniaceæ.* Flowers unisexual. Sepals in the males 4; in the females 5. Stamens indefinite; anthers collected in a head, the connective very thick. Ovary winged, 3-celled, with 3 double polyspermous placentæ in the axis; stigmas 3, somewhat spiral. Fruit 3-celled, with an indefinite number of minute seeds; embryo without albumen. Herbaceous plants or under-shrubs. Leaves alternate, oblique. Stipules scarious.

Group 3.—Parietosae.

Placentæ parietal, or arising from the base of carpels combined into a 1-celled ovary.

Alliance 1.—Cruciales. *Embryo curved. Albumen absent.*

Order 40.—*Brassicaceæ* or *Cruciferæ.* Petals 4, deciduous, cruciate. Petals 4, cruciate. Stamens 6, of which two are shorter. Ovary superior, with parietal placentæ, meeting in the middle, and forming a spurious dissepiment. Fruit a silique or silicule. Seeds attached by a funiculus, generally pendulous. Embryo with the radicle folded upon the cotyledons. Herbaceous plants. Leaves alternate. Flowers without bracts.

Order 41.—*Capparidaceæ.* Sepals 4. Petals 4, cruciate. Stamens definite or indefinite. Disk hemispherical, or elongated. Ovary stalked. Fruit 1-celled, most frequently with two polyspermous placentæ; embryo incurved. Herbaceous plants, shrubs, or trees, without true stipules. Leaves alternate.

Order 42.—*Resedaceæ.* Calyx many-parted. Petals lacerated, unequal. Disk 1-sided. Stamens perigynous, definite. Ovary sessile, 3-lobed, 1-celled, many seeded, with 3 parietal placentæ. Fruit opening at the apex. Embryo arcuate. Herbaceous plants with alternate leaves, and gland-like stipules.

Alliance 2.—Violales. *Stamens few, with no collection of abortive petals or stamens into an external ring. Embryo never curved.*

Order 43.—*Violaceæ.* Sepals 5, persistent, imbricate. Petals 5. Stamens hypogynous; filaments dilated, elongated beyond the anthers. Ovary 1-celled with 3 parietal placentæ; style with a hooded stigma. Capsule of 3 valves, bearing the placentæ in their axis. Herbaceous plants or shrubs. Leaves stipulate with an involute vernation.

Sub-order—*Sauvagesiæ.* Stamens opposite the petals. Five hypogynous scales. Seeds adhering to the edges of the valves.

Order 44.—*Samydaceæ.* Sepals 3, 5, or 7, usually coloured inside. Petals 0. Stamens from the tube of the calyx, 2, 3, or 4 times as many as the sepals;

filaments monadelphous. Ovary superior, 1-celled; stigma capitate, ovules indefinite, attached to parietal placentæ. Capsule coriaceous; with from 3 to 5 valves, many-seeded, often somewhat pulpy inside. Seeds fixed to the valves without order, with a fleshy aril; albumen fleshy. Trees or shrubs. Leaves alternate, with stipules, usually with pellucid markings, which are both round and linear.

Order 45.—*Moringaceæ.* Calyx of 5 nearly equal divisions, the tube lined with a fleshy disk. Corolla of 5 nearly equal petals. Stamens from the top of the tube of the calyx; filaments slightly petaloid. Ovary stipitate, with 3 placentæ. Fruit a long pod-like capsule with 3 valves. Seeds sometimes winged, embryo without albumen. Trees. Leaves pinnate, with an odd leaflet.

Order 46.—*Droseraceæ.* Sepals imbricate. Petals 5, hypogynous. Stamens distinct, either equal in number to the petals, or 2, 3, or 4 times as many. Styles 3-5. Capsule of 3 or 5 valves. Embryo in the axis of a fleshy or cartilaginous albumen. Herbaceous plants, often covered with glands. Leaves with stipulary fringes and a circinate vernation. Peduncles circinate.

Order 47.—*Frankeniaceæ.* Sepals 4-5, in a furrowed tube. Petals hypogynous, unguiculate, with appendages at the base of the limb. Stamens hypogynous; style 2- or 3-fid. Capsule 1-celled, enclosed in the calyx, 2-3- or 4-valved, many seeded. Seeds attached to the margins of the valves, very minute; embryo in the midst of albumen. Herbaceous plants or under-shrubs. Stems much branched. Leaves opposite, exstipulate, with a membranous sheathing base.

Alliance 3.—Passionales. *Flowers with a ring or crown of sterile stamens. Petioles generally glandular. Embryo never curved so that the radicle lies on the cotyledons.*

Order 48.—*Passifloraceæ.* Sepals 5, their tube lined with filamentous processes. Petals 5. Stamens monadelphous. Ovary stalked, 1-celled; styles 3; stigmas simple, clavate. Fruit with 3 polyspermous placentæ. Seeds with a brittle sculptured testa. Embryo in fleshy albumen. Usually climbers. Leaves alternate, with leafy stipules. Flowers often enclosed in an involucre.

Order 49.—*Papayaceæ.* Flowers unisexual. Calyx minute, toothed. Corolla gamopetalous; in the male with 5 lobes and 10 stamens; in the female divided nearly to the base. Ovary with 5 polyspermous placentæ; stigma sessile, 5-lobed, lacerated. Fruit succulent. Seeds enveloped in a loose mucous coat with pitted testa; embryo in the axis of fleshy albumen. Trees yielding an acrid milky juice. Leaves alternate.

Order 50.—*Flacourtiaceæ.* Sepals from 4-7. Petals equal to them in number. Stamens hypogynous, occasionally changed into nectariferous scales. Ovary roundish; stigmas several, more or less distinct. Fruit 1-celled, the centre filled with a thin pulp. Seeds few, attached to the surface of the valves in a branched manner. Embryo in the axis of albumen. Shrubs or trees. Leaves alternate without stipules.

Order 51.—*Malesherbiaceæ.* Calyx tubular, membranous, 5-lobed. Petals persistent, convolute, arising from without a rim or corona. Stamens 5 or 10, perigynous; filaments distinct. Ovary stipitate; styles 3, filiform. Fruit membranous more or less, many-seeded. Seeds arising either from the axis of the valves, or from their base; no aril; embryo in the midst of fleshy albumen. Herbaceous or half-shrubby plants. Leaves alternate, without stipules.

Order 52.—*Turneraceæ.* Calyx often coloured, with 5 lobes, imbricated. Petals 5, equal, twisted; stamens distinct. Ovary with 3 placentæ; ovules indefinite; styles 3 or 6, cohering more or less. Capsule 3-valved, the valves bearing the placentæ in the middle. Seeds with a thin aril on one side; embryo in the middle of fleshy albumen. Herbaceous plants. Leaves alternate, without stipules, with occasionally two glands at the apex of the petiole.

Alliance 4.—Bixales. *Polyandrous, without any crown of sterile stamens. Leaves usually dotted.*

Order 53.—*Bixaceæ.* Sepals 4-7, imbricated. Petals of a like number. Stamens indefinite, distinct. Ovary sessile; placentæ 4-7; style 1-2-4. Fruit many-seeded. Seeds enveloped in pulp. Albumen hardly present. Trees or shrubs. Leaves alternate with deciduous stipules and pellucid dots.

Group 4.—Calycosae.

Calyx incompletely whorled, two of the sepals being exterior. Placentæ not parietal in the ovary. Fruit never inferior. Albumen, if present, of nearly the same volume as the embryo.

Alliance 1.—Guttales. *Stamens indefinite. Albumen absent. Petals and sepals equal in number.*

Order 54.—*Clusiaceæ* or *Guttiferæ*. Sepals 2 to 6 persistent. Petals hypogynous, 4 to 10. Stamens numerous, hypogynous. Disk fleshy, occasionally 5-lobed. Ovary 5- or many-celled; ovules solitary, erect, or ascending, or numerous and attached to central placentæ; style very short; stigma peltate or radiate. Seeds frequently nestling in pulp, frequently with an aril; albumen none. Trees or shrubs. Leaves without stipules, opposite, coriaceous.

Sub-order—Canelleæ. Seeds albuminous.

Order 55.—*Rhizobolaceæ*. Sepals 5, imbricated. Petals 5, thickish. Stamens extremely numerous, slightly monadelphous. Ovary 4-6-celled; stigma simple. Fruit of 4-6 combined nuts; each nut 1-seeded, 1-celled, with a thick double putamen. Seed uniform, without albumen; radicle very large, constituting nearly the whole of the almond-like nut. Trees. Leaves opposite, without stipules.

Order 56.—*Marcgraaviaceæ*. Sepals 2 to 7. Corolla hypogynous; sometimes gamopetalous. Stamens indefinite; anthers long. Ovary usually furrowed, many-celled, many-seeded; stigma simple or capitate; ovules numerous attached to a central placenta. Capsule coriaceous. Seeds very minute and numerous, nestling in pulp. Shrubs. Leaves alternate. Peduncles naked, or furnished with either simple or cucullate hollow bracts.

Order 57.—*Hypericaceæ*. Sepals 4-5, persistent, unequal, with glandular dots. Petals 4-5, hypogynous, twisted, oblique, often having black dots. Stamens indefinite, hypogynous. Styles several. Fruit a capsule or berry, of many valves and many cells. Seeds minute, indefinite; embryo straight, with no albumen.—Herbaceous plants, shrubs or trees. Leaves opposite, entire, sometimes dotted. Flowers generally yellow.

Sub-order—Ochrantheæ. Stamens definite. Stipules. Serrated leaves.

Alliance 2.—Theales. *Stamens indefinite in number. Albumen absent. The petals and sepals not equal to each other in number, gradually passing the one into the other.*

Order 58.—*Ternstromiaceæ*. Sepals 5 or 7, coriaceous, deciduous. Petals not equal in number to the sepals. Stamens numerous; monadelphous or polyadelphous. Ovary with several cells; styles filiform. Capsule 2-7-celled; usually with a central column. Seeds large, attached to the axis, very few; albumen none; cotyledons occasionally plaited lengthwise. Trees or shrubs. Leaves alternate, without stipules, now and then with pellucid dots.

Alliance 3.—Acerales. *Stamens definite in number. Flowers usually unsymmetrical in their parts, or more or less irregular; in the majority small and disposed in a compound inflorescence.*

Order 59.—*Aceraceæ*. Calyx imbricated. Petals inserted round an hypogynous disk. Stamens inserted upon an hypogynous disk, generally 8. Ovary 2-lobed; style 1; fruit of 2 parts, which are samaroid; each 1-celled; with one or two seeds; albumen none. Trees. Leaves opposite, wthiout stipules. Flowers often polygamous.

Order 60.—*Sapindaceæ*. Flowers polygamous. Calyx imbricated. Petals hypogynous, sometimes naked, sometimes with a doubled appendage in the inside, imbricated. Disk fleshy. Stamens 8-10, rarely 5-6-7. Ovary 3-celled, the cells containing 1, 2, 3, very seldom more, ovules. Fruit sometimes capsular, sometimes samaroid, sometimes fleshy and indehiscent. Seeds usually with an aril. Albumen 0. Trees, or shrubs which often climb and have tendrils.

Sub-order—Millingtonieæ. Flowers minute, very irregular. Stamens opposite the petals, 3 sterile, 2 fertile. Ovary 2-celled. Fruit a 1-celled drupe.

Order 61.—*Æsculaceæ*. Calyx campanulate, 5-lobed. Petals 4 or 5, unequal,

hypogynous. Stamens 7-8, unequal. Ovary 3-celled; ovules 2 in each cell. Fruit 1-2- or 3-valved. Seeds large, roundish, with a broad hilum; albumen none; embryo curved, germinating under ground. Trees or shrubs. Leaves opposite, without stipules, quinate or septenate. Racemes terminal.

Order 62.—*Polygalaceæ.* Sepals 5, very irregular, often glumaceous. Petals hypogynous, usually 3, of which 1 is anterior and larger than the rest. Stamens hypogynous, 8, usually in a tube; anthers innate, 1-celled and opening at their apex. Ovary with 2 or 3 cells; ovules solitary, pendulous. Seeds pendulous, with a caruncula next the hilum; albumen abundant. Shrubs or herbaceous plants. Leaves alternate, destitute of stipules. Pedicels with 3 bracts.

Order 63.—*Vochyaceæ.* Sepals 4-5, the upper one calcarate. Petals 1, 2, 3, or 5. Stamens 1-5, from the bottom of the calyx. Ovary superior, 3-celled; ovules solitary or twin, attached to the base of the axis. Capsule 3-cornered, 3-celled, 3-valved. Seed without albumen, erect. Trees. Branches opposite, when young 4-cornered. Leaves opposite, with 2 stipules.

Alliance 4.—Cistales. *Flowers regular. Albumen present in the seeds.*

Order 64.—*Elatinaceæ.* Sepals 3-5. Petals hypogynous. Stamens hypogynous. Ovary 3-5-celled; styles 3-5; stigmas capitate. Fruit capsular. Seeds numerous, embryo straight, with but little albumen. Annuals. Leaves opposite with stipules. Flowers minute.

Order 65.—*Linaceæ.* Sepals 3-4-5, imbricated, persistent. Petals hypogynous, unguiculate, twisted. Stamens united in an hypogynous ring. Ovary with about as many cells as sepals. Styles equal in number to the cells; stigmas capitate. Capsule many-celled. Seeds in each cell single, inverted; albumen present. Herbaceous plants or small shrubs. Leaves without stipules, usually alternate. Petals fugitive.

Order 66.—*Hugoniaceæ.* Calyx without an involucre, permanent, the sepals very unequal. Petals 5, shortly unguiculate, twisted. Stamens 10, hypogynous, slightly monadelphous. Ovary stalked, 5-celled; ovules 2, pendulous. Styles 5, distinct. Fruit containing 5 bony nuts. Embryo in the axis of fleshy albumen. Shrubs. Leaves alternate, with subulate stipules. Peduncles often transformed into circinate spines.

Order 67.—*Chlenaceæ.* Involucre 1-2-flowered. Sepals 3, small. Petals 5 or 6, hypogynous. Stamens either very numerous or 10. Ovary 3-celled; style 1. Capsule 3-celled. Seeds solitary or numerous, suspended; albumen firm. Trees or shrubs. Leaves alternate, with stipules.

Order 68.—*Cistaceæ.* Sepals 5, persistent, unequal, the three inner twisted. Petals 5, crumpled, twisted in a direction contrary to that of the sepals. Stamens indefinite, hypogynous. Ovary 1- or many-celled; ovules with their foramen at their apex; style single; stigma simple. Fruit either 1-celled with parietal placentæ, or imperfectly 5- or 10-celled. Seeds indefinite. Embryo inverted, either spiral or curved in the midst of mealy albumen. Radicle remote from the hilum. Shrubs or herbaceous plants. Leaves usually entire, stipulate or exstipulate.

Order 69.—*Reaumuriaceæ.* Calyx 5-parted, surrounded externally by imbricated bracts. Petals 5, hypogynous. Stamens hypogynous. Ovary superior; styles several, filiform. Fruit with 2 to 5 valves. Seeds definite, villous, erect; embryo surrounded by a mealy albumen; radicle next the hilum. Shrubs. Leaves fleshy, scale-like, without stipules. Flowers solitary.

Group 5.—Syncarposæ.

The carpels united into a solid pistil. Calyx not having the sepals in a broken whorl. Placentæ not parietal. Ovary not inferior. Carpels not placed obliquely upon a central gynobase; or if they are, then either in more rows than one or of a larger number than 5.

Alliance 1.—Malvales. *Æstivation of calyx valvate. Carpels* 4 *or more. Stamens generally monadelphous; the calyx long and tubular when that is not the case. Hairs mostly starry.*

Order 70.—*Sterculiaceæ.* Petals hypogynous, convolute, often saccate at the base. Stamens definite or indefinite, some among them often sterile; anthers

2-celled, sometimes anfractuose. Pistil often seated upon a gynophore. Styles equal in number to the carpels; ovules erect. Seeds often winged, sometimes woolly; albumen oily or fleshy, rarely wanting; cotyledons foliaceous, flat, and plaited. Trees or shrubs. Leaves alternate, with stipules.

Order 71.—*Malvaceæ.* Sepals 3 or 4, hypogynous, twisted. Stamens indefinite, monadelphous; anthers 1-celled, reniform. Ovary formed by the union of several carpels; styles the same number as the carpels. Fruit either capsular or baccate; albumen none; embryo curved, with twisted and doubled cotyledons. Herbaceous plants, trees, or shrubs. Leaves alternate, stipulate.

Order 72.—*Elæocarpaceæ.* Sepals 4 or 5. Petals 4 or 5, hypogynous, lobed or fringed at the point. Disk glandular. Stamens hypogynous or perigynous, some multiple of the sepals; filaments short, distinct; anthers long, filiform, 4-cornered, opening by an oblong pore at the apex. Ovary two or many-celled. Fruit variable. Seeds 1, 2, or more in each cell; albumen fleshy. Trees or shrubs. Leaves alternate, simple, with deciduous stipules.

Order 73.—*Dipteraceæ.* Calyx tubular, 5-lobed, unequal, afterwards enlarged, imbricated. Petals contorted. Stamens indefinite, hypogynous, distinct; anthers subulate, opening longitudinally towards the apex. Ovary without a disk, few-celled; ovules in pairs, pendulous; style single. Fruit surrounded by the calyx, having tough, leafy, enlarged, permanent divisions. Seed single, without albumen. Cotyledons crumpled. Trees. Leaves alternate, involute invernation; stipules deciduous.

Order 74.—*Tiliaceæ.* Sepals 4 or 5. Petals 4 or 5, usually with a little pit at their base. Stamens hypogynous, distinct; anthers 2-celled. Ovary single, composed of from 4 to 10 carpels; style one; stigmas as many as the carpels. Fruit dry. Seeds numerous; embryo erect in the axis of fleshy albumen, with flat foliaceous cotyledons. Trees or shrubs, very seldom herbaceous plants. Leaves stipulate, alternate.

Order 75.—*Lythraceæ.* Calyx monosepalous. Petals inserted between the lobes of the calyx, very deciduous. Stamens inserted into the tube of the calyx below the petals. Ovary 2- or 4-celled; style filiform; capsule membranous, covered by the calyx, usually 1-celled. Seeds numerous, without albumen. Herbs, rarely shrubs. Branches frequently 4-cornered. Leaves without stipules.

Alliance 2.—Meliales. *Æstivation of calyx imbricated. Carpels* 4 *or a larger number. Stamens very generally monadelphous in a kind of cup. Seldom or never hairy.*

Order 76.—*Meliaceæ.* Sepals 3, 4, or 5. Petals hypogynous, usually valvate. Stamens twice as many as the petals; filaments cohering in a long tube; anthers sessile within the orifice of the tube. Ovary with 3, 10, 12 cells; ovules 1-2 in each cell. Fruit often 1-celled. Seeds without albumen, not winged. Trees or shrubs. Leaves alternate, without stipules.

Order 77.—*Cedrelaceæ.* Calyx 4-5-cleft. Petals 4-5. Stamens 8-10, either united or distinct. Style and stigma simple. Seeds flat-winged. Trees with timber which is usually compact, scented and beautifully veined. Leaves alternate, without stipules.

Order 78.—*Humiriaceæ.* Calyx 5-parted. Stamens hypogynous, numerous, monadelphous; anthers with a fleshy connective extended beyond the lobes. Ovary 5-celled; ovules 1-2 suspended; style simple. Fruit drupaceous. Embryo in fleshy albumen. Trees or shrubs. Leaves alternate, without stipules.

Order 79.—*Aurantiaceæ.* Calyx urceolate or campanulate, short. Petals 3-5, inserted upon the outside of an hypogynous disk. Stamens inserted upon an hypogynous disk; filaments sometimes combined in one or several parcels. Ovary many-celled, style 1; stigma thickish. Fruit many-celled, filled with pulp. Seeds usually pendulous; raphe and chalaza distinctly marked. Trees or shrubs, almost always smooth and filled with transparent receptacles of oil. Leaves alternate, often compound, always articulated with the petiole.

Order 80.—*Spondiaceæ.* Calyx 5-cleft. Petals 5, inserted below a disk surrounding the ovary. Stamens 10, perigynous. Disk annular. Ovary 2-5-celled, styles 5; stigmas obtuse; ovule 1 in each cell, pendulous. Fruit drupaceous, 2-5-celled. Seeds without albumen. Trees without spines. Leaves alternate, without pellucid dots.

Alliance 3.—Rhamnales. *Æstivation of the calyx valvate. Carpels fewer than 4, sometimes slightly adhering to the calyx. Hairs if present never starry. All shrubs.*

Order 81.—*Rhamnaceæ.* Calyx 4-5-cleft, valvate. Petals distinct, inserted into the orifice of the calyx. Stamens definite, opposite the petals. Ovary superior, or half-superior, 2- 3- or 4-celled; ovules solitary, erect. Albumen fleshy; embryo with large flat cotyledons, and a short inferior radicle. Trees or shrubs. Leaves alternate with minute stipules. Flowers axillary or terminal, minute.

Order 82.—*Chailletiaceæ.* Sepals with an incurved valvate æstivation. Petals alternate with the sepals, and arising from the base of the calyx. Stamens 5; glands 5, hypogynous, opposite the petals. Ovary 2- 3-celled. Ovules twin, pendulous; style simple. Fruit drupaceous, 1- 2- or 3-celled. Seeds without albumen. Trees or shrubs. Leaves alternate, with two stipules. Flowers small, axillary.

Order 83.—*Tremandraceæ.* Sepals 4 or 5, equal, valvular, deciduous. Petals involute, much larger than the calyx. Stamens hypogynous, 2 before each petal; anthers 2- or 4-celled, opening by a pore at the apex. Ovary 2-celled; ovules from 1 to 3, pendulous. Fruit capsular. Seeds with a thickened appendage at the apex; embryo in the axis of a fleshy albumen. Slender heath-like shrubs. Leaves without stipules. Flowers often large and showy.

Order 84.—*Nitrariaceæ.* Calyx 5-toothed. Corolla of 5 petals which arise from the calyx, with an inflexed valvular æstivation. Stamens 3 times the number of the petals, perigynous. Ovary 3- or more-celled, with a fleshy style; ovules pendulous, by means of a long funiculus. Fruit drupaceous. Seeds with no albumen. Shrubs, with succulent alternate leaves, which are sometimes fascicled.

Order 85.—*Burseraceæ.* Calyx persistent, with from 2 to 5 divisions. Petals 3-5, inserted below a disk; æstivation valvate. Stamens 2 or 4-times as many as the petals, perigynous. Ovary 2-5-celled; style 1; ovules in pairs, attached to the axis. Fruit drupaceous. Seeds without albumen. Trees or shrubs. Leaves alternate, equally pinnate, occasionally with stipules, usually without pellucid dots.

Alliance 4.—Euphorbiales. *Æstivation of calyx imbricated. Carpels fewer than four; very often three. Hairs frequently starry if present.*

Order 86.—*Euphorbiaceæ.* Flowers monœcious or diœcious. Calyx lobed, sometimes wanting. Corolla consisting of petals or scales, or absent. Stamens definite or indefinite. Ovary superior, 2- or 3-celled; ovules solitary or twin, suspended; styles equal in number to the cells; stigma compound or single. Fruit generally consisting of 3 dehiscent cells, separating with elasticity from their common axis; embryo in fleshy albumen. Trees, shrubs, or herbaceous plants, often abounding in acrid milk. Leaves opposite or alternate, usually with stipules. Flowers sometimes enclosed within an involucre.

Order 87.—*Empetraceæ.* Flowers unisexual. Sepals hypogynous, imbricated scales. Stamens equal in number to the inner sepals, and alternate with them. Ovary 3- 6- or 9-celled; ovules solitary, ascending; stigma radiating. Fruit fleshy, 3- 6- or 9-celled; the coating of the cells bony; embryo in the axis of fleshy watery albumen. Small acrid shrubs with heath-like evergreen leaves and minute flowers.

Order 88.—*Stackhousiaceæ.* Calyx 1-leaved, 5-cleft, with an inflated tube. Petals 5, arising from the top of the tube of the calyx; their claws combined in a tube longer than the calyx. Stamens 5, unequal, arising from the throat of the calyx. Ovary 3- or 5-lobed, the lobes with a single erect ovule; styles from 3 to 5, sometimes combined. Fruit of from 3 to 5 indehiscent pieces. Embryo in the axis of fleshy albumen. Herbaceous plants. Leaves simple, alternate. Stipules very minute.

Order 89.—*Fouquieraceæ.* Sepals 5, imbricated. Petals in a long tube, regular. Stamens 10-12, inserted on the calyx. Style filiform; ovules numerous. Capsule 3-celled, 3-valved; seeds winged. Embryo in the centre of thin fleshy albumen. Trees or shrubs. Leaves fleshy, clustered in the axil of a spine.

Order 90.—*Celastraceæ.* Sepals 4 or 5, imbricated, inserted into the margin

of an expanded torus. Petals imbricate. Stamens alternate with the petals, inserted into the disk. Disk large, expanded, flat, closely surrounding the ovary. Ovary with 3 or 4 cells; ovules ascending; albumen fleshy. Shrubs. Leaves simple. Flowers in axillary cymes, minute.

Sub-order—Hippocrateæ. Sepals and petals 5. Stamens 3.

Sub order—Trigonieæ. Sepals and petals unequal, the latter papilionaceous. Stamens 10-12, monadelphous, out of the centre.

Order 91.—*Staphyleaceæ.* Sepals 5, coloured, imbricated. Petals 5, imbricated. Stamens alternate with the petals, perigynous. Disk large, urceolate. Ovary 2- or 3-celled, superior; ovules erect; styles 2 or 3, cohering. Fruit membranous or fleshy. Seeds with a bony testa; hilum large; albumen none. Shrubs. Leaves opposite, pinnate, with both common and partial stipules.

Order 92.—*Malpighiaceæ.* Sepals generally with a definite number of conspicuous glands. Petals 5, unguiculate; stamens seldom fewer. Ovary 1, of 3 carpels, more or less combined; ovules suspended. Fruit dry or berried. Seeds without albumen. Small trees or shrubs, sometimes climbing. Leaves opposite, with stipules.

Sub-order—Erythroxyleæ. Petals sessile, with a plaited scale at the base. Albumen horny. Shrubs or trees. Young shoots covered with imbricated scales. Leaves alternate with axillary stipules.

Alliance 5.—Silenales. *Embryo rolled round mealy albumen; or if this is not the case, herbaceous plants with the joints of the stem tumid; or with scales replacing leaves upon rod-like branches. Almost all herbs or small shrubs.*

Order 93.—*Portulacaceæ.* Sepals 2. Petals generally 5. Stamens inserted irregularly into the calyx, or hypogynous, variable in number. Ovary 1-celled; style single, stigmas several. Capsule 1-celled. Seeds attached to a central placenta. Embryo curved round the albumen. Succulent shrubs or herbs. Leaves without stipules, sometimes with membranous ones. Flowers usually ephemeral.

Order 94.—*Silenaceæ.* Sepals 4-5, united into a permanent tube. Petals stalked. Stamens hypogynous, definite. Ovary stalked, usually many-seeded with a free central placenta. Stigmas sessile, 2-5. Capsule 2-5 valved. Seeds usually with the embryo curved round mealy albumen. Herbaceous plants with opposite undivided exstipulate leaves, and tumid nodes.

Order 95.—*Alsinaceæ.* Sepals 4-5. Petals often 2-lobed, deciduous, on the outside of a ring, which is more or less perigynous. Stamens inserted into the ring. Ovary 1-celled, many-seeded. Stigmas 2-5, linear, sessile. Capsule 1-celled. Seeds attached to a free central placenta. Embryo curved round mealy albumen. Herbaceous plants with tumid joints. Leaves opposite, undivided, often connate. Stipules none.

Order 96.—*Tamaricaceæ.* Calyx 4-or 5-parted, persistent. Petals withering. Stamens hypogynous, distinct or monadelphous. Stigmas 3. Capsule 3-valved, 1-celled, many-seeded. Seeds ascending, comose; embryo straight. Shrubs or herbs, with rod-like branches. Leaves alternate, resembling scales.

Order 97.—*Illecebraceæ.* Sepals 3, 4, or 5. Petals minute. Stamens perigynous. Ovary superior; styles 2-5. Fruit small, dry, 1-celled, rarely 3-celled. Seeds upon a central placenta, embryo lying on one side of the albumen. Herbaceous or half-shrubby plants, with entire leaves and scarious stipules. Flowers minute, with scarious bracts.

Group 6.—Gynobaseosæ.

Carpels about 5 in a single whorl, diverging at the base in consequence of the interposition of a conical gynobase. Stamens usually hypogynous.

Alliance 1.—Rutales. *Style single, or leaves marked with pellucid dots.*

Order 98.—*Ochnaceæ.* Sepals persistent, imbricated. Petals hypogynous, sometimes twice as many as the sepals. Stamens 5, 10, or indefinite, hypogynous; anthers opening by pores. Carpels upon an enlarged fleshy disk, style one; ovule erect. Fruit of many pieces, somewhat drupaceous, 1-seeded. Seeds without albumen. Very smooth trees or shrubs. Leaves alternate, with stipules.

Order 99.—*Simarubaceæ.* Flowers hermaphrodite, or unisexual. Calyx in 4 or 5 divisions. Petals longer; æstivation twisted. Stamens arising from the back of an hypogynous scale. Ovary 4- or 5-lobed upon a stalk, each cell with 1 suspended ovule; style simple. Fruit indehiscent; embryo without albumen. Trees or shrubs. Leaves without stipules, alternate, without dots.

Order 100.—*Rutaceæ.* Flowers hermaphrodite, sometimes irregular. Sepals 4-5. Petals sometimes combined. Stamens definite, hypogynous, on the outside of a cup-like disk. Ovary few-celled; ovules 2-4; style single, occasionally divided near the base. Fruit capsular. Embryo with or without albumen; radicle superior. Trees or shrubs (or herbs). Leaves exstipulate, dotted.

Order 101.—*Zygophyllaceæ.* Flowers hermaphrodite. Calyx convolute. Petals unguiculate. Stamens dilated at the base, sometimes placed on the back of a small scale, hypogynous. Ovary with a disk with 4 or 5 cells; ovules pendulous or erect; style simple. Fruit capsular, rarely fleshy, with angles or wings. Seeds fewer than the ovules; radicle superior; albumen whitish. Herbaceous plants, shrubs or trees; branches often articulated at the joints. Leaves opposite, with stipules, not dotted.

Order 102.—*Xanthoxylaceæ.* Flowers unisexual. Calyx in 3, 4, or 5 divisions. Petals usually longer than the calyx, convolute. Stamens equal to the petals in number, or twice as many. Ovary of the same number of carpels as there are petals, or of a smaller number; ovules 2; styles more or less combined. Fruit berried or membranous, sometimes consisting of several drupes or 2-valved capsules. Seeds solitary or twin, pendulous, usually smooth and shining; embryo lying within fleshy albumen; radicle superior. Trees or shrubs. Leaves without stipules, with pellucid dots.

Alliance 2.—Geraniales. *Styles distinct, at least near the point. Carpels combined in the ovary. Leaves never dotted. Stamens very often monadelphous.*

Order 103.—*Geraniaceæ.* Sepals 5, ribbed. Petals 5, unguiculate. Stamens definite, hypogynous, often monadelphous. Fruit of 5 elastic cocci rolling back from a long-beaked gynobase to which the hardened styles adhere. Seeds solitary, pendulous, without albumen. Cotyledons convolute and plaited. Herbs or shrubs with stipulate leaves. Stems tumid, and separable at the joints.

Order 104.—*Balsaminaceæ.* Sepals irregular; the odd sepal spurred. Petals irregular. Stamens 5, symmetrical. Carpels consolidated into a 5-celled ovary. Fruit capsular, with 5 elastic valves. Seeds solitary, or numerous, suspended; albumen none. Succulent herbaceous plants. Leaves without stipules.

Sub-order.—*Tropæoleæ.* Fruit indehiscent; the lobes fleshy and 1-seeded.

Order 105.—*Oxalidaceæ.* Sepals 5, equal. Petals equal, unguiculate. Stamens 10, more or less monadelphous. Styles 5; stigmas capitate. Fruit capsular, membranous, with 5 cells. Seeds few, within a fleshy integument, which expels the seeds with elasticity. Albumen between cartilaginous and fleshy. Herbaceous plants, undershrubs, or trees. Leaves alternate, compound.

Alliance 3.—Coriales. *Styles and carpels perfectly distinct.*

Order 106.—*Coriariaceæ.* Flowers hermaphrodite, monœcious or diœcious. Calyx 5-parted. Petals 5, fleshy, with an elevated keel. Stamens 10. Ovary 5-celled, 5-angled; stigmas 5, subulate. Ovules solitary. Carpels 5, indehiscent, 1-seeded, sometimes surrounded with glandular lobes. Albumen none. Shrubs with opposite branches. Leaves simple, entire.

Order 107.—*Surianaceæ.* Calyx 5-parted. Petals equal, shortly clawed. Stamens indefinite, hypogynous. Carpels 5, 1-celled with 2 ascending ovules, stigmas simple. Pericarp woody. Seed solitary, erect. Embryo annular, without albumen. Woody plants. Leaves alternate, without stipules.

Alliance 4.—Flörkeales. *Herbs. A simple style. Fruit divided into deep lobes. Gynobase never fleshy. Stamens perigynous.*

Order 108.—*Limnanthaceæ.* Calyx 3- 5-parted, valvate. Petals convolute. Stamens perigynous; the filaments opposite the sepals having a projection on the outside. A thin perigynous disk. Carpels combined by a single style. Nuts 3-5, berried, 1-seeded. Seed erect; embryo large, amygdaloid, without albumen. Soft herbaceous plants. Leaves divided, without stipules. Flowers axillary.

Group 7.—Apocarposae.

Carpels distinct, either wholly or in part. Ovary with neither a gynobase nor parietal placentæ. Calyx not in a broken whorl. No epigynous disk.

Alliance 1.—Rosales. *Albumen wholly absent.*

Order 109.—*Rosaceæ.* Calyx with a disk lining the tube. Petals perigynous, equal. Stamens indefinite, arising from the calyx. Ovaries superior, solitary or several, 1-celled; sometimes cohering into a plurilocular pistil; styles lateral. Fruit 1-seeded nuts, or acini, or follicles, containing several seeds. Embryo straight. Herbaceous plants or shrubs. Leaves simple or compound, alternate, usually with stipules.

Sub-order.—Pomeæ. Calyx superior. Ovary adhering more or less to the sides of the calyx and each other; ovules ascending. Fruit a pome. Albumen none. Trees or shrubs.

Sub-order.—Amygdaleæ. Calyx inferior. Carpel solitary. Fruit a drupe. Trees or shrubs.

Sub-order.—Sanguisorbeæ. Flowers often unisexual. Calyx with a thickened tube. Petals none. Stamens definite. Ovary solitary, simple. Ovule solitary. Nut solitary, enclosed in the tube of the calyx. Embryo without albumen. Herbaceous plants or undershrubs, occasionally spiny.

Order 110.—*Fabaceæ* (or *Leguminosæ*). Calyx inferior, the segments often unequal, and variously combined. Petals either papilionaceous or regularly spreading. Stamens definite or indefinite, perigynous, or hypogynous. Ovary simple, superior. Fruit a legume. Seeds destitute of albumen. Herbaceous plants, shrubs, or trees. Leaves alternate; petiole tumid at the base. Stipules 2.

Sub-order.—Cæsalpinieæ. Petals regularly spreading, imbricated. Stamens perigynous.

Sub-order.—Mimoseæ. Sepals and petals valvate. Stamens hypogynous.

Order 111.—*Connaraceæ.* Calyx 5-parted, persistent. Petals inserted on the calyx, imbricated. Stamens hypogynous, filaments usually monadelphous. Ovary solitary and simple, or several; ovules 2, ascending; stigmas usually dilated. Fruit dehiscent. Seeds often with an aril. Trees or shrubs. Leaves compound, not dotted, alternate, without stipules.

Order 112.—*Chrysobalanaceæ.* Calyx 5-lobed. Petals more or less irregular, either 5 or none. Stamens definite or indefinite, usually irregular. Ovary superior, solitary, cohering more or less on one side with the calyx; ovules erect. Fruit, a drupe with 1 or 2 cells. Seed solitary, erect. Embryo with no albumen. Trees or shrubs. Leaves simple, alternate, stipulate, with veins that run parallel with each other from the midrib to the margin.

Order 113.—*Calycanthaceæ.* Sepals and petals confounded, indefinite, combined in a fleshy tube. Stamens inserted in a fleshy rim. Anthers adnate, turned outwards. Ovaries several, simple; ovules solitary. Nuts enclosed in the fleshy tube of the calyx, 1-seeded. Albumen none; cotyledons convolute. Shrubs with square stems. Leaves opposite, simple, without stipules.

Alliance 2.—Saxales. *Carpels two, diverging at the end, many-seeded. Embryo in the axis of albumen.*

Order 114.—*Baueraceæ.* Sepals inferior. Petals the same number. Stamens indefinite; anthers bursting by pores. Carpels little inferior. Fruit capsular. Shrubs. Leaves toothed, ternate, opposite, without stipules.

Order 115.—*Cunoniaceæ.* Calyx 4- or 5-cleft, half superior. Petals 4 or 5. Stamens perigynous, definite. Styles sometimes combined. Fruit capsular or indehiscent. Embryo in the axis of fleshy albumen. Trees or shrubs. Leaves opposite, compound, or simple, with interpetiolar stipules.

Order 116.—*Saxifragaceæ.* Calyx superior or inferior. Petals 5, or none. Stamens 5-10, perigynous or hypogynous; anthers bursting longitudinally. Disk hypogynous or perigynous, rarely consisting of 5 scales. Styles none. Stigmas sessile on the tips of the lobes of the ovary. Fruit membranous. Seeds numerous, very minute. Embryo taper, in the axis of fleshy albumen. Herbaceous plants. Leaves simple.

Alliance 3.—Crassales. *Carpels several, quite distinct, continuous with the styles. Seeds very numerous with albumen.*

Order 117.—*Crassulaceæ.* Sepals from 3 to 20. Petals either distinct or cohering. Stamens inserted with the petals. Hypogynous scales several, 1 at the base of each carpel. Ovaries of the same number as the petals, opposite to which they are placed. Fruit of several follicles, opening in their face. Seeds variable in number. Succulent herbs or shrubs. Stipules none. Flowers usually in cymes.

Alliance 4.—Balsamales. *Carpels neither two and diverging at the apex; nor numerous with an hypogynous scale. Leaves and bark abounding in balsamic juice.*

Order 118.—*Amyridaceæ.* Calyx minute. Petals 4-5, imbricated. Stamens definite, hypogynous. Ovary superior, 1-celled; stigma capitate; ovules pendulous. Fruit indehiscent, glandular. Seed without albumen; radicle superior. Resinous trees or shrubs. Leaves compound, with pellucid dots.

Order 119.—*Anacardiaceæ.* Flowers unisexual. Calyx small. Petals perigynous, imbricated. Stamens usually definite. Disk fleshy, hypogynous. Ovary single, very rarely 5 or 6; styles 1 or 3, occasionally 4; ovule solitary, attached by a cord to the bottom of the cell. Fruit indehiscent. Seed without albumen. Trees or shrubs, with a resinous caustic juice. Leaves alternate, without pellucid dots.

Sub-Class II.—INCOMPLETÆ.

Corolla absent. Calyx consisting of distinct sepals, or of several combined into a tube; very often incomplete; often absent.

Group 1.—Rectembryosae.

Calyx exceedingly imperfect, often rudimentary. Embryo straight, with or without albumen.

Alliance 1.—Amentales. *Flowers in catkins. Carpels two or more, combined. Trees or arborescent shrubs.*

Order 120.—*Corylaceæ* or *Cupuliferæ.* Flowers unisexual. Stamens 5 to 20. Ovaries crowned by the rudiments of a calyx, within a coriaceous involucre, with several cells and several ovules; ovules pendulous. Fruit a 1-celled nut, enclosed in the involucre. Seeds solitary. Trees or shrubs. Leaves with stipules, alternate.

Order 121.—*Betulaceæ.* Flowers unisexual, monœcious, males sometimes having a calyx. Stamens definite, usually distinct. Ovary superior, 2-celled; ovules pendulous. Fruit membranous, indehiscent, 1-celled. Seeds pendulous; albumen none. Trees or shrubs. Leaves alternate, with stipules.

Order 122.—*Scepaceæ.* Flowers diœcious. Males in catkins. Calyx minute and membranous. Stamens 2-5. Females in axillary racemes. Calyx of six sepals, inferior. Ovary with two cells; style 0; stigma with short lobes; ovules pendulous, with a broad scale projecting from the placenta and covering over the foramen. Capsule 2-celled. Seeds enveloped in a succulent aril; embryo in the axis of albumen. Trees. Leaves coriaceous, alternate, with membranous stipules.

Alliance 2.—Urticales. *Carpels solitary, or more than one combined in a syncarpous pistil. Stamens continuous, without sheaths. Flowers never producing fruit with a cupule.*

Order 123.—*Garryaceæ.* Flowers diœcious. Males: calyx 4-leaved. Stamens 4. Females: calyx superior, 2-toothed. Ovary 1-celled; ovules 2, pendulous. Pericarp berried, indehiscent, 2-seeded. Embryo very minute, in the base of fleshy albumen. A shrub. Leaves opposite, without stipules. Flowers in pendulous amentaceous racemes.

Order 124.—*Hensloviaceæ.* Flowers diœcious. Calyx with a woolly disk, valvate. Males: stamens 5, perigynous; anthers 2-celled, with a broad connective and oblique lobes, bursting longitudinally. Females: ovary superior, 2-celled; ovules indefinite. Trees with opposite entire exstipulate leaves.

Order 125.—*Trewiaceæ.* Flowers diœcious. Males: sepals 3-4, valvate. Stamens numerous. Females: calyx inferior. Style 4-cleft. Drupe 4-celled, with a single seed in each. Embryo inverted and furnished with albumen. A tree. Leaves opposite, exstipulate, entire.

Order 126.—*Urticaceæ.* Flowers monœcious or diœcious. Calyx membranous. Stamens definite, turned backwards with elasticity. Ovary superior, simple; ovule solitary; stigma simple. Fruit, a nut. Embryo with or without albumen; radicle always superior. Trees, shrubs or herbs, sometimes lactescent. Leaves alternate, usually covered with asperities or stinging hairs; with stipules.

Sub-order.—Ceratophylleæ. Calyx many-parted. Stamens 12-20. Nut 1-seeded, terminated by the hardened stigma. Seed pendulous; embryo with 4 cotyledons, and a many-leaved placenta.

Order 127. *Ulmaceæ.* Flowers hermaphrodite. Calyx campanulate, inferior, irregular. Stamens definite. Ovary 2-celled; ovules solitary, pendulous. Fruit 1- or 2-celled, indehiscent, membranous or drupaceous. Seed pendulous; albumen none; radicle superior. Trees or shrubs, with scabrous alternate leaves and stipules.

Order 128.—*Stilaginaceæ.* Flowers unisexual. Calyx 3-5-parted. Stamens 2 or more, from a tumid receptacle. Anthers 2-lobed, with vertical lobes opening transversely. Ovary superior; stigma 3-4-toothed. Fruit drupaceous. Seed solitary, suspended, albuminous. Trees or shrubs. Leaves alternate, stipulate.

Order 129.—*Myricaceæ.* Flowers unisexual, amentaceous, achlamydeous. Stamens 6 or 8. Ovary 1-celled, surrounded by several hypogynous scales; ovule solitary, erect; stigmas 2. Fruit drupaceous, or dry and dehiscent. Seed solitary, erect; radicle superior. Leafy shrubs, with resinous glands and dots, leaves alternate.

Order 130.—*Juglandaceæ.* Flowers unisexual. Calyx in the males membranous; in the females superior. Petals in the males 0; in the females occasionally present. Stamens indefinite, hypogynous. Ovary inferior, incompletely 2-4-celled; ovule solitary, erect. Fruit drupaceous, 1-celled, with 4 imperfect partitions. Seed 4-lobed; radicle superior. Trees. Leaves alternate, pinnated, without pellucid dots or stipules.

Alliance 3.—Casuarales. *Carpels solitary. Stems jointed and furnished with sheaths.*

Order 131.—*Casuaraceæ.* Flowers unisexual. Males. Flowers whorled about the articulations of the jointed rachis. Bracts membranous. Stamen 1. Females in dense spikes. Rachis not jointed. Calyx 0. Ovary lenticular. Styles 2. Caryopsides winged. Seed erect without albumen. Branching weeping trees, with jointed shoots. Leaves 0.

Alliance 4.—Datiscales. *Carpels several. Seeds numerous. Leaves alternate.*

Order 132.—*Datiscaceæ.* Flowers unisexual. Calyx of the males in several pieces; of the females superior, toothed. Stamens several. Ovary 1-celled, with polyspermous parietal placentæ. Fruit capsular, 1-celled. Seeds with a cupulate strophiole; embryo without albumen. Herbaceous branched plants. Leaves alternate without stipules.

Order 133.—*Lacistemaceæ.* Calyx in several narrow divisions, inferior. Stamens hypogynous, on one side of the ovary, with a thick 2-lobed connective. Ovary superior, 1-celled, with several ovules attached to parietal placentæ. Fruit capsular, 1-celled. Seed suspended, with a fleshy aril; albumen fleshy; embryo inverted. Small trees or shrubs. Leaves simple, with stipules.

Group 2.—Achlamydosae.

Neither calyx nor corolla present.

Alliance 1.—Piperales. *Carpels either solitary, or if more than one quite distinct. Flowers in spikes. Embryo minute in the base of fleshy albumen.*

Order 134.—*Chloranthaceæ.* Flowers hermaphrodite or unisexual. Stamens

lateral; anthers 1-celled, with a fleshy connective. Ovary 1-celled. Ovule pendulous. Fruit drupaceous. Embryo minute at the apex of fleshy albumen. Herbaceous plants. Stems jointed. Leaves opposite with intervening stipules.

Order 135.—*Saururaceæ.* Flowers hermaphrodite. Stamens 6, clavate, persistent. Ovaries 4, distinct; ovules solitary, ascending; or a 3- 4-celled pistil. Nuts 4, indehiscent; or 3- 4-celled capsule. Embryo minute in a fleshy sac, on the outside of hard mealy albumen. Herbaceous marsh or water plants. Leaves alternate with stipules.

Order 136.—*Piperaceæ.* Flowers hermaphrodite. Stamens definite or indefinite. Ovary superior, 1-celled, containing a single erect ovule; stigma sessile, simple. Fruit somewhat fleshy, indehiscent. Seed erect, with the embryo lying in a fleshy sac placed at that end of the seed which is opposite the hilum, on the outside of the albumen. Shrubs or herbaceous plants. Leaves without stipules. Flowers usually sessile in spikes.

Alliance 2.—Salicales. *Flowers amentaceous. Fruit mostly many-seeded. When one-seeded in globular heads.*

Order 137.—*Salicaceæ.* Flowers unisexual, amentaceous. Ovary superior, 1- or 2-celled; ovules numerous, erect. Fruit coriaceous, 1- or 2-celled, 2-valved, many-seeded. Seeds comose; albumen 0. Trees or shrubs. Leaves alternate, simple, with stipules.

Order 138.—*Platanaceæ.* Flowers amentaceous. Stamens single. Ovaries terminated by a thick style, having the stigmatic surface on one side; ovules solitary, or two, suspended. Nuts clavate. Seeds solitary; embryo in the axis of fleshy albumen. Trees or shrubs. Leaves alternate, with scarious sheathing stipules. Catkins round.

Order 139.—*Balsamaceæ.* Catkins unisexual, roundish. Anthers numerous, nearly sessile; ovaries 2-celled, styles 2. Fruit, a kind of cone composed of indurated connected scales, in the cavities of which lie 2-lobed 2-celled capsules. Seeds compressed, membranous, winged. Embryo inverted in the midst of albumen. Tall trees, yielding balsam. Leaves alternate, with glandular serratures. Stipules deciduous.

Alliance 3.—Monimiales. *Flowers within an involucre. Sexes distinct.*

Order 140.— *Monimiaceæ.* Involucre tubular, valvular. Stamens indefinite, covering all the inside of the involucre; anthers bursting longitudinally. Ovaries superior, 1-celled, inclosed within the tube of the involucre; ovule pendulous. Fruit consisting of 1-seeded nuts, enclosed within the enlarged involucre; embryo in the midst of an abundant albumen. Aromatic trees or shrubs. Leaves opposite, without stipules. Flowers axillary in short racemes.

Order 141.—*Atherospermaceæ.* Involucre calyx-like, tubular, divided into segments placed in two rows. Stamens very numerous in the bottom of the involucre; anthers bursting with a valve. Ovaries usually indefinite. Nuts terminated by the persistent styles become feathery. Seed erect; embryo at the base of soft fleshy albumen. Trees. Leaves opposite, without stipules. Flower-heads axillary, solitary.

Alliance 4.—Podostemales. *Flowers solitary. Carpels 2 or 3, combined. Seeds numerous and minute.*

Order 142.—*Podostemaceæ.* Flowers in a membranous lacerated spathe. Stamens hypogynous, 1-00. Ovary 2- 3-celled; ovules numerous, attached to a central placenta. Fruit capsular; seeds numerous, minute. Herbs growing under water, with capillary leaves and inconspicuous flowers; or with leaves and stem confounded in one leafy expansion.

Alliance 5.—Callitrichales. *Carpels several, combined, single-seeded. Floating plants.*

Order 143.—*Callitrichaceæ.* Flowers unisexual, with 2 fistular bracts. Stamens single; anthers 1-celled. Ovary solitary, 4-cornered, 4-celled; ovules solitary, peltate. Fruit 4-celled, 4-seeded, indehiscent; embryo inverted in the axis of fleshy albumen. Aquatic herbaceous plants, with opposite, simple leaves. Flowers very minute.

Group 3.—Tubiferosae.

Calyx tubular, often resembling a corolla. Ovary usually single. Embryo never curved round albumen.

Alliance 1.—Santalales. *Calyx adherent to the ovary. Anthers opening by longitudinal fissures.*

Order 144.—*Santalaceæ.* Calyx half-coloured, valvate. Stamens 4-5 inserted in the base of the calyx. Ovary 1-celled. Ovules 1-4 pendulous from the top of a central placenta. Style single. Fruit 1-seeded, indehiscent. Embryo in the axis of albumen. Trees, shrubs, or herbaceous plants. Leaves alternate, without stipules. Flowers small.

Alliance 2.—Daphnales. *Calyx inferior, with an imbricated æstivation. Carpel solitary. Anthers opening by longitudinal fissures.*

Order 145.—*Elæagnaceæ.* Males: calyx 4-parted; stamens 3 to 8, sessile. Female: calyx inferior, tubular, persistent. Ovary 1-celled; ovule ascending; stigma subulate. Fruit enclosed within the calyx; embryo surrounded by fleshy albumen. Trees or shrubs with a scurfy surface. Leaves entire, without stipules. Flowers axillary, often fragrant.

Order 146.—*Thymelaceæ.* Calyx inferior, tubular, coloured. Stamens definite, in the orifice of its tube. Ovary with one pendulous ovule. Fruit nut-like or drupaceous. Albumen none, or thin; embryo straight; radicle superior. Stem shrubby. Leaves without stipules.

Order 147.—*Hernandiaceæ.* Flowers monœcious, with a calycine involucre to the females. Calyx petaloid, inferior, 4-8-parted. Stamens definite in two rows. Ovary 1-celled; ovule pendulous; stigma peltate. Embryo inverted without albumen. Trees. Leaves alternate.

Order 148.—*Aquilariaceæ.* Calyx tubular, 5-cleft, with bearded scales. Stamens 10 or 5. Ovary superior 1-celled; ovules two suspended; stigma large, simple. Capsule 1-celled, 2-valved. Seeds one on each placenta with a tail-like aril; albumen 0; radicle superior. Trees. Leaves alternate without stipules.

Alliance 3.—Proteales. *Calyx valvate. Stamens opposite its lobes. Fruit simple, follicular.*

Order 149.—*Proteaceæ.* Calyx valvular. Stamens 4, opposite the segments of the calyx. Ovary superior; style simple; stigma undivided. Fruit dehiscent or indehiscent. Seed without albumen. Shrubs or small trees. Leaves hard, dry, without stipules.

Alliance 4.—Laureales. *Anthers opening by valves. Carpels solitary, superior or inferior.*

Order 150.—*Lauraceæ.* Calyx 4-6-cleft, imbricated. Stamens definite, perigynous; anthers 2-4-celled, bursting by a valve. Glands at the base of the inner filaments. Ovary superior with one or two pendulous ovules. Fruit baccate. Seed without albumen; embryo inverted. Trees. Leaves without stipules, alternate.

Order 151.—*Illigeraceæ.* Calyx adherent to the ovary; the border divided in two rows, valvular. Stamens in the top of the tube, furnished at the base with glands. Anthers 2-celled, opening by a valve. Ovary inferior, 1-celled; ovule pendulous; stigma peltate. Fruit indehiscent, seed without albumen; cotyledons twisted.

Order 152.—*Cassythaceæ.* Stem dodder-like, leafless. Stamens 9, without glands; anthers 4-celled. Caryopsis included in the berried perianth.

Alliance 5.—Penæales. *Carpels several. Calyx imbricated or valvate.*

Order 153.—*Penæaceæ.* Calyx inferior with bracts at its base, hypocrateriform, limb valvate or imbricated. Stamens either 4 or 8. Ovary superior, 4-celled. Fruit capsular 4-celled. Seed with a nucleus or solid fleshy mass, with no distinction of albumen or embryo. Shrubs. Leaves opposite, imbricated, without stipules.

Group 4.—Columnosae.

Stamens usually monadelphous, and ovary 3-6-celled; or the latter with an inferior ovary. Wood, without concentric zones.

Alliance 1.—Nepenthales. *Spiral vessels between wood and bark. Diœcious. Ovary superior.*

Order 154.—*Nepenthaceæ.* Diœcious. Calyx inferior. Stamens in a column; anthers opening externally. Ovary superior, 4-cornered, 4-celled; stigma sessile. Fruit capsular, with the seeds sticking to the sides of the dissepiments. Seeds indefinite, minute; fusiform. Embryo in the midst of fleshy albumen. Herbaceous or half-shrubby plants. Leaves alternate, with a dilated foliaceous petiole, pitcher-shaped at end. Stem without concentric zones.

Alliance 2.—Aristolochiales. *Ovary inferior.*

Order 155.—*Aristolochiaceæ.* Hermaphrodite. Calyx superior, valvate Stamens epigynous. Ovary inferior, 3- or 6-celled; style simple; stigmas radiating. Fruit 3- or 6-celled, many-seeded. Seeds with a minute embryo in the base of fleshy albumen. Herbaceous plants or shrubs. Leaves alternate, often with leafy stipules. Wood without concentric zones. Flowers brown, or some dull colour.

Group 5.—Curvembryosae.

Embryo curved round albumen, or having the form of a horse-shoe, or spiral; calyx rarely tubular, sometimes long and petaloid.

Alliance 1.—Chenopodiales. *Albumen present. Radicle next the hilum.*

Order 156.—*Amarantaceæ.* Calyx scarious persistent, immersed in dry coloured bracts. Stamens hypogynous. Ovary superior, 1 or few-seeded; ovules hanging from a free central funiculus. Fruit a utricle. Seeds lentiform; albumen farinaceous; embryo curved round the circumference; radicle next the hilum. Herbs or shrubs. Leaves simple, without stipules. Flowers in heads or spikes, usually coloured.

Order 157.—*Chenopodiaceæ.* Calyx sometimes tubular at the base, persistent. Stamens inserted into the base of the calyx, opposite its segments. Ovary superior, with a single ovule attached to the base of the cavity. Fruit membranous. Embryo curved round farinaceous albumen, or spiral, or doubled together without albumen. Herbaceous plants or under-shrubs. Leaves alternate without stipules. Flowers small.

Order 158.—*Tetragoniaceæ.* Like the last, but ovary consisting of several cells.

Order 159.—*Phytolaccaceæ.* Calyx of 4 or 5 petaloid leaves. Stamens indefinite, or if equal to the number of the divisions of the calyx alternate with them. Ovary of from 1 to several cells, each containing 1 ascending ovule. Fruit baccate or dry, 1 or many-celled. Seeds solitary, with a cylindrical embryo curved round mealy albumen. Under-shrubs or herbaceous plants. Leaves alternate, without stipules, often with pellucid dots.

Alliance 2.—Polygonales. *Albumen present. Radicle at the end of the embryo most remote from the hilum.*

Order 160.—*Polygonaceæ.* Calyx inferior, imbricated. Stamens definite. Ovary superior, with a single erect ovule. Nut triangular. Seed with farinaceous albumen; embryo inverted; radicle remote from the hilum. Herbaceous plants, rarely shrubs. Leaves alternate, their stipules cohering in the form of an ochrea.

Alliance 3.—Petiveriales. *Albumen absent. Cotyledons spiral.*

Order 161.—*Petiveriaceæ.* Calyx of several distinct leaves. Stamens perigynous, indefinite, or if equal to the segments of the calyx, alternate. Ovary superior 1-celled; ovule erect. Fruit 1-celled, indehiscent, dry. Seed without albumen; radicle inferior. Under-shrubs or herbaceous plants, with an alliaceous odour. Leaves alternate, with distinct stipules, often with minute pellucid dots.

Alliance 4.—Sclerales. *Tube of the calyx hardened.*

Order 162.—*Scleranthaceæ.* Hermaphrodite. Calyx 4 or 5-toothed. Stamens from 1 to 10. Ovary simple, superior, 1-seeded. Fruit a utricle inclosed within the hardened calyx. Seed pendulous from a funiculus; embryo cylindrical, curved round farinaceous albumen. Small herbs. Leaves opposite, without stipules. Flowers axillary, sessile.

Order 163.—*Nyctaginaceæ.* Calyx tubular, somewhat coloured; becoming indurated at the base. Stamens definite, hypogynous. Ovary superior, with a single erect ovule. Fruit a utricle, enclosed within the base of the calyx; embryo with foliaceous cotyledons, wrapping round floury albumen. Stem either herbaceous, shrubby, or arborescent. Leaves opposite, and almost always unequal; sometimes alternate. Flowers having an enclosure which is either common or proper.

Alliance 5.—Cocculales. *Albumen present. Flowers formed upon a ternary plan, with the divisions of the calyx in two rows.*

Order 164.—*Menispermaceæ.* Flowers unisexual, usually very small. Sepals in one or several rows. Stamens monadelphous or distinct. Anthers turned outwards. Ovaries numerous, each with one style, sometimes soldered together into a many-celled body; which is occasionally in consequence of abortion; 1-celled. Drupes berried, 1-seeded; embryo curved lying in albumen; radicle superior. Shrubs with a sarmentaceous habit. Leaves alternate. Flowers small.

Sub-order.—Lardizabaleæ. Carpels many-seeded. Leaves compound.

Sub-class III.—MONOPETALÆ.

Group 1.—Polycarposae.

Ovary of several carpels either combined or distinct.

Alliance 1.—Brexiales. *Albumen absent. Carpels 5. Sterile stamens between the fertile ones. Seeds indefinite.*

Order 165.—*Brexiaceæ.* Calyx inferior, 5-parted. Petals 5, hypogynous, imbricated. Stamens 5, hypogynous, from a cup, toothed between each stamen. Ovary 5-celled, ovules attached in two rows to the axis; style 1. Fruit drupaceous; albumen 0. Trees, with nearly simple trunks. Leaves coriaceous, alternate, with stipules.

Alliance 2.—Ericales. *Anthers opening by pores, hard and dry, often with appendages. Carpels from 4 to 5 or more.*

Order 166.—*Pyrolaceæ.* Calyx 4-5-leaved, inferior. Corolla regular, 4-5-parted. Stamens hypogynous; anthers opening by pores. Ovary 4-5-celled; style declinate; stigma indusiate. Fruit capsular, many-seeded. Seeds winged. Embryo minute, at the base of fleshy albumen. Usually herbaceous plants. Leaves simple.

Order 167.—*Monotropaceæ.* The same as Pyrolaceæ, except, style straight; anthers bursting longitudinally; embryo minute, at the apex of fleshy albumen; stems leafless, or nearly so, but covered with fleshy scales. Parasitical plants.

Order 168.—*Ericaceæ.* Calyx 4 or 5-cleft, inferior. Corolla hypogynous, 4- or 5-cleft, imbricated. Stamens definite, hypogynous; anthers 2-celled, dehiscing by a pore. Ovary many-celled, many-seeded; style 1. Fruit capsular. Seeds indefinite, minute; embryo in the axis of albumen. Shrubs or under shrubs. Leaves evergreen, rigid, without stipules.

Order 169.—*Vaccinaceæ.* In all things like the last, but ovary inferior.

Order 170.—*Epacridaceæ.* Same as Ericaceæ, but anthers 1-celled, and opening longitudinally.

Alliance 3.—Primulales. *Anthers bursting longitudinally without appendages. Carpels 4-5. Fruit often 1-celled.*

Order 171.—*Primulaceæ.* Calyx 4-5-cleft, persistent. Corolla regular. Stamens inserted upon the corolla opposite its segments. Ovary 1-celled;

O 2

style 1: stigma capitate. Capsule with a central placenta. Embryo lying across the hilum in fleshy albumen. Herbaceous plants.

Order 172.—*Myrsinaceæ.* Calyx 4- or 5-cleft. Corolla hypogynous. Stamens opposite the segments of the corolla; filaments distinct, sometimes 5, sterile, petaloid. Ovary 1 with a free central placenta, style 1. Fruit fleshy, mostly 1-seeded. Seeds peltate; albumen horny; embryo lying across the hilum. Trees or shrubs. Leaves alternate, serrated, coriaceous; stipules wanting.

Order 173.—*Sapotaceæ.* Calyx regular, persistent. Corolla hypogynous, its segments usually equal in number to those of the calyx, seldom twice or thrice as many. Stamens arising from the corolla, definite. Anthers usually turned outward; sterile stamens. Ovary with several cells, 1 erect ovule. Style 1. Fruit baccate. Seeds nut-like. Testa bony, shining. Embryo large, usually in fleshy albumen. Trees or shrubs. Leaves alternate, without stipules, coriaceous.

Order 174.—*Ebenaceæ.* Calyx in 3 or 6 divisions. Corolla hypogynous, usually pubescent, imbricated. Stamens definite; twice as many as the segments of the corolla, four times as many, or the same number. Ovary several-celled, the cells having 1 or 2 ovules, pendulous; style divided. Fruit fleshy, few-seeded. Albumen cartilaginous; embryo in the axis; radicle turned towards the hilum. Trees or shrubs without milk. Leaves alternate, coriaceous.

Sub-order.—Styraceæ. Ovary inferior. Stamens perigynous. Style simple.

Order 175.—*Aquifoliaceæ.* Sepals 4 to 6, imbricated. Corolla hypogynous. Stamens alternate with its segments. Disk none. Ovary with from 2 to 6 cells; ovules solitary, pendulous. Fruit indehiscent, with from 2 to 6 stones. Seed suspended; albumen large; embryo small, 2-lobed. Trees or shrubs. Leaves coriaceous. Flowers small.

Alliance 4.—Nolanales. *Fruit divided into distinct lobes.*

Order 176.—*Nolanaceæ.* Calyx 5-parted. Corolla plaited, usually thickened in the tube. Stamens alternate with the segments of the corolla. Pistil several carpels, either distinct, or partially combined; style single. Stigma capitate. Fruit enclosed in the calyx; pericarp woody. Seeds ascending, solitary; embryo curved, with a small quantity of albumen. Herbaceous, or suffruticose plants. Leaves alternate, without stipules.

Alliance 5.—Volvales. *Carpels* 2-4, *combined. Anthers never opening by pores.*

Order 177.—*Convolvulaceæ.* Calyx persistent, in 5 divisions, remarkably imbricated, often unequal. Corolla hypogynous, plaited. Stamens 5, inserted into the base of the corolla. Ovary with 2 or 4 cells; few seeded; ovules erect; style 1. Disk annular. Capsule with the valves fitting at their edges to the angles of a loose dissepiment. Seeds with mucilaginous albumen; embryo curved; cotyledons shrivelled. Herbaceous plants or shrubs, usually twining and milky. Leaves alternate.

Order 178.—*Cuscutaceæ.* Calyx persistent, 4- 5-parted, imbricated. Corolla persistent, imbricated. Scales alternating with segments of corolla; stamens opposite the last. Ovary 2-celled; ovules in pairs erect; styles 2. Capsule. Embryo spiral, acotyledonous, in fleshy albumen. Leafless parasites.

Order 179.—*Polemoniaceæ.* Calyx 5-parted. Corolla regular, 5-lobed. Stamens 5, unequal, on the tube of the corolla. Ovary 3-celled; stigma 3-lobed. Capsule 3-celled; 3-valved, the valves separating from the axis. Embryo in the axis of horny albumen. Herbaceous plants. Leaves opposite.

Order 180.—*Diapensiaceæ.* Calyx of 5 sepals, which are much imbricated. Corolla regular, imbricated. Stamens arising from the margin of the corolla; anthers 2-celled, with a broad connective, bursting transversely. Disk 0. Ovary 3-celled; style single. Capsule membranous. Seeds peltate. Embryo slender, lying across the hilum in fleshy albumen. Under-shrubs, with small imbricated leaves.

Order 181.—*Hydroleaceæ.* Calyx 5-parted, slightly imbricated. Corolla regular. Stamens from between the lobes of the corolla, regular; anthers with a narrow connective. Ovary 2- or 3-celled; styles 2 or 3. Fruit capsular, enclosed in the calyx. Seeds indefinite, very small; albumen fleshy; embryo orthotropous. Herbaceous plants, or under-shrubs. Leaves alternate, with stipules.

Group 2,—Epigynosæ.

Ovary inferior, usually with an epigynous disk; composed of two or more carpels. Anthers never bursting by pores. Stamens always inserted into the corolla.

Alliance 1.—Campanales. *Stipules absent. Seeds indefinite in number.*

Order 182.—*Lobeliaceæ.* Calyx 5-lobed, or entire. Corolla irregular, 5-lobed, or 5-cleft. Stamens 5; anthers cohering. Stigma fringed. Fruit capsular, 1- or more celled, many-seeded; embryo in the axis of albumen. Herbaceous plants or shrubs. Leaves alternate, without stipules.

Order 183.—*Campanulaceæ.* Calyx persistent. Corolla usually 5-lobed, withering, regular, valvate. Stamens alternate with the lobes of the corolla. Anthers distinct. Stigma naked. Fruit dehiscing by apertures, or valves. Seeds numerous; embryo in the axis of albumen. Herbaceous plants or under-shrubs, yielding a white milk. Leaves alternate, without stipules.

Sub-order ?—Sphenocleaceæ. Corolla 5-parted, inflexed. Stamens 5 in the recesses of the corolla. Ovary 2-celled. Capsule circumscissile; embryo without albumen. Flowers minute.

Order 184?—*Belvisiaceæ.* Calyx persistent. Corolla plaited, many-lobed, deciduous. Stamens definite or indefinite. Stigma lobed. Fruit berried, many-seeded. Shrubs. Leaves alternate, entire, without stipules.

Order 185.—*Columelliaceæ.* Calyx 5-parted. Corolla 5-8-parted, imbricated. Stamens 2; anthers 3-lobed, sinuous. Stigma capitate. Disk epigynous, fleshy. Fruit 2-celled, many-seeded. Shrubs or trees. Leaves opposite, without stipules.

Order 186.—*Stylidiaceæ.* Calyx 2-6-parted, permanent. Corolla irregular, imbricated. Stamens 2, connate into an elastic slender column, with which the style is consolidated. Ovary 2-celled. Capsule 2-valved, many-seeded. Seeds albuminous. Glandular herbs.

Alliance 2.—Goodeniales. *Stigma with an indusium.*

Order 187.—*Goodeniaceæ.* Calyx equal, or unequal. Corolla more or less irregular, split at the back; the segments folded inwards in æstivation. Stamens 5, distinct. Ovary with indefinite ovules; stigma surrounded by a membranous cup. Fruit a capsule; albumen fleshy. Herbaceous plants, rarely shrubs, without milk. Leaves scattered, without stipules.

Order 188.—*Scævolaceæ.* Calyx sometimes obsolete. Corolla irregular, split at the back, the edges of the divisions folded inwards in æstivation. Stamens 5, distinct; anthers distinct or united. Ovary few-celled, with solitary erect ovules; stigma surrounded by a cup. Fruit drupaceous or nucamentaceous. Herbaceous plants with the flowers axillary or terminal and never in heads.

Alliance 3.—Cinchonales. *Stipules between the leaves.*

Order 189.—*Cinchonaceæ.* Calyx simple. Corolla tubular, regular, valvate or imbricated. Stamens all on the same line. Ovary surmounted by a disk; ovules numerous or few. Fruit either splitting, or indehiscent and dry, or succulent. Seeds definite or indefinite; embryo small, surrounded by horny albumen. Trees, shrubs, or herbs. Leaves simple, opposite or verticillate, with interpetiolary stipules.

Order 190.—*Lygodysodeaceæ.* In all things Cinchonaceous, except, ovary 1-celled, with 2 ovules. Pericarp brittle, 1-celled. Placentæ 2, free. Seeds 2, pendulous from the apex of the placentæ. Albumen 0. Twining shrubs. Stipules single between the petioles.

Alliance 4.—Capriales. *Stipules wanting. Leaves opposite. Seeds definite.*

Order 191.—*Caprifoliaceæ.* Calyx 4-5-cleft, with bracts at its base. Corolla monopetalous or polypetalous, rotate or tubular, regular or irregular. Stamens epipetalous. Ovary with from 1 to 3 or 4 cells. Fruit indehiscent, 1 or more celled. Embryo straight in fleshy albumen. Shrubs or herbaceous plants, with opposite leaves, destitute of stipules.

Alliance 5.—Stellales. *Fruit didymous. Leaves whorled without stipules. Stem angular.*

Order 192.—*Galiaceæ*, or *Stellatæ*. Calyx 4- 5- or 6-lobed. Corolla rotate or tubular, regular. Stamens equal in number to the lobes of the corolla. Ovary 2-celled; ovules solitary, erect. Fruit a didymous, indehiscent pericarp. Embryo straight in horny albumen. Herbaceous plants, with whorled leaves, destitute of stipules. Angular stems.

Group 3.—Aggregosae.

Only one perfect carpel present.

Alliance 1.—Asterales *or* Compositæ. *Anthers syngenesious. Flowers in heads surrounded by an involucre.*

Order 193.—*Calyceraceæ*. Albumen present; seed pendulous.

Order 194.—*Mutisiaceæ*. Albumen absent; seed erect. Corolla bilabiate.

Order 195.—*Cichoraceæ*. Albumen absent; seed erect. Corolla ligulate, or 1-lipped. Juice milky.

Order 196.—*Asteraceæ* or *Corymbiferæ*. Albumen absent; seed erect. Involucre hemispherical. Florets of the ray ligulate if present.

Order 197.—*Cynaraceæ* or *Cynarocephalæ*. Albumen absent; seed erect. Involucre rigid or spiny, conical.

Alliance 2.—Dipsales. *Anthers distinct. Ovary inferior.*

Order 198.—*Dipsaceæ*. Calyx superior, membranous; surrounded by an involucel. Corolla oblique, imbricated. Stamens 4; anthers distinct. Ovary 1-celled with a pendulous ovule; stigma simple. Fruit crowned by the pappus-like calyx; embryo in fleshy albumen. Herbaceous plants or under-shrubs. Leaves opposite or whorled. Flowers surrounded by a many-leaved involucre.

Order 199.—*Valerianaceæ*. Calyx superior, membranous, or resembling pappus. Corolla tubular, regular or irregular, sometimes calcarate. Stamens 1 to 5. Ovary with 1 perfect cell, and 2 other abortive ones; ovule pendulous; stigmas 1 to 3. Fruit dry. Embryo destitute of albumen. Herbs. Leaves opposite, without stipules. Flowers corymbose, panicled, or in heads.

Alliance 3.—Brunoniales. *Style single. Stigma with an indusium. Flowers in heads.*

Order 200.—*Brunoniaceæ*. Calyx inferior, with bracts at the base. Corolla almost regular, 5-parted. Stamens definite, hypogynous; anthers slightly cohering. Ovary 1-celled with an erect ovule; stigma in a cup. Fruit membranous, enclosed within the indurated tube of the calyx. Seed without albumen. Herbaceous plants. Leaves radical, with no stipules.

Alliance 4.—Plantales. *Flowers on scapes. Style single. Stigma naked. Ovary superior. Flowers in heads, or spikes, or panicles.*

Order 201.—*Plantaginaceæ*. Calyx 4-parted. Corolla membranous, hypogynous, 4-parted. Stamens 4; filaments flaccid; anthers versatile. Ovary without a disk; ovules peltate or erect, solitary, twin, or indefinite; stigma hispid, simple. Capsule membranous. Embryo in fleshy albumen. Herbaceous plants, with spiked inconspicuous flowers.

Order 202.—*Globulariaceæ*. Calyx persistent, 5-cleft, sometimes 2-lipped. Corolla hypogynous, bilabiate, made up of 5 parts. Stamens 4, from the tube of the corolla. Ovary superior, 1-celled, with a pendulous ovule. Albumen fleshy. Shrubs or herbs. Leaves alternate. Flowers in heads.

Order 203.—*Salvadoraceæ*. Calyx inferior, 4-leaved. Corolla 4-parted. Stamens connecting the petals. Ovary superior, 1-celled, with a sessile stigma; ovule erect. Embryo amygdaloid, without albumen. Shrubs. Leaves opposite. Flowers minute.

Alliance 5.—Plumbales. *Styles 5. Flowers quinary. Ovary superior.*

Order 204.—*Plumbaginaceæ*. Calyx tubular, plaited. Corolla regular. Stamens definite. Ovary superior, 1-seeded; ovule pendulous, from an umbilical

cord; styles 5. Fruit a utricle. Seed inverted. Herbaceous plants, or shrubs. Leaves alternate, undivided, somewhat sheathing.

Group 4.—Nucamentosae.

Fruit consisting of 4 bony lobes, which are either originally distinct, or which become distinct more or less when fully ripe, or which are separable into little nuts. If capsular, inflorescence gyrate.

Alliance 1.—Phaceliales. *Fruit capsular. Inflorescence gyrate.*

Order 205.—*Hydrophyllaceæ.* Calyx 5-cleft, with reflexed appendages. Corolla regular. Stamens 5, epipetalous. Ovary simple, 1-celled; placentæ 2. Fruit 2-valved. Seeds reticulated; embryo cartilaginous. Herbaceous plants. Leaves usually lobed.

Alliance 2.—Echiales. *Fruit nucamentaceous. Inflorescence gyrate. Flowers symmetrical.*

Order 206.—*Cordiaceæ.* Calyx 5-toothed. Corolla regular. Stamens alternate with the segments of the corolla. Ovary 4-celled, with 1 pendulous ovule in each cell; stigma 4-cleft. Fruit drupaceous, 4-celled. Seed pendulous by a funiculus; cotyledons plaited; albumen 0. Trees. Leaves scabrous, without stipules.

Order 207.—*Ehretiaceæ.* Calyx 5-parted, imbricated. Corolla tubular, imbricated. Stamens from the bottom of the tube. Ovary in an annular disk, 2- or more celled; stigma simple; ovules suspended. Seed solitary; embryo in thin albumen. Trees or shrubs, with harsh pubescence. Leaves alternate, without stipules.

Order 208.—*Boraginaceæ.* Calyx persistent. Corolla hypogynous, regular. Stamens upon the petals, equal to the lobes of the corolla. Ovary 4-parted, 4-seeded; style simple; stigma simple or bifid. Nuts 4, distinct. Seed without albumen. Herbaceous plants or shrubs. Stems round. Leaves alternate, covered with asperities.

Alliance 3.—Labiales. *Fruit nucamentaceous. Inflorescence terminal or axillary. Flowers unsymmetrical, often didynamous.*

Order 209.—*Lamiaceæ* or *Labiatæ.* Calyx tubular, persistent. Corolla bilabiate. Stamens didynamous, the 2 upper sometimes wanting. Ovary 4-lobed; style 1; stigma bifid. Fruit 1 to 4 small nuts. Seeds with no albumen. Herbaceous plants or under-shrubs. Stem 4-cornered. Leaves opposite, replete with aromatic oil. Flowers in axillary cymes; sometimes solitary.

Order 210.—*Verbenaceæ.* Calyx tubular. Corolla irregular. Stamens didynamous, occasionally 2. Ovary 2- or 4-celled; ovules erect or pendulous; style 1; stigma bifid. Fruit composed of 2 or 4 nucules in a state of adhesion; albumen none. Trees or shrubs, sometimes herbaceous plants. Leaves opposite, without stipules. Flowers in opposite corymbs, or spiked alternately; sometimes in dense heads.

Order 211.—*Myoporaceæ.* Calyx 5-parted. Corolla tubular, nearly equal or 2-lipped. Stamens didynamous. Ovary 2-4-celled; ovules pendulous. Fruit a 2-4-celled drupe. Seeds albuminous. Shrubs with little hairiness. Flowers axillary, without bracts.

Order 212.—*Selaginaceæ.* Calyx tubular, rarely of two sepals. Corolla tubular, hypogynous, more or less irregular. Stamens usually didynamous, seldom 2; anthers 1-celled. Ovary superior, very minute. Disk fleshy. Fruit 2-celled, the cells 1-seeded, membranous. Seed pendulous; embryo in fleshy albumen. Herbaceous plants or shrubs. Leaves alternate, often fascicled. Flowers sessile, spiked, with large bracts.

Order 213.—*Stilbaceæ.* Calyx tubular. Corolla hypogynous, somewhat 2-lipped, valvate. Stamens inserted into the top of the tube of the corolla, the upper one always rudimentary, or obliterated; anthers 2-celled. Ovary superior, 2-celled; ovule erect; stigma simple. Disk 0. Fruit 1-seeded surrounded by the calyx. Leaves whorled, narrow, rigid, without stipules. Flowers in dense spikes.

Group 5.—Dicarposae.

Carpels 2, capsular, with a distinct central placenta; never nucamentaceous. Flowers never gyrate.

Alliance 1.—Bignoniales. *Flowers unsymmetrical, usually didynamous. Seeds often with wings or tail-like processes. Albumen* 0. *Stalks of the seeds never hooked.*

Order 214.—*Pedaliaceæ.* Calyx of 5 pieces. Corolla irregular; rather valvate. Disk hypogynous fleshy. Stamens didynamous. Ovary 1- or 2-celled, sometimes with spurious cells; stigma 2-lobed. Fruit hard and woody or membranous. Seeds not winged; albumen none. Herbaceous plants with nearly opposite leaves. Flowers each with two bracts.

Order 215.—*Bignoniaceæ.* Calyx sometimes spathaceous. Corolla irregular. Stamens 5, of which 1 always and sometimes 3 are sterile. Ovary in a disk, 2-celled, polyspermous; style 1; stigma of 2 plates. Capsule 2-valved, 2-celled, long and compressed. Seeds often winged; albumen 0. Trees or shrubs, often twining or climbing. Leaves opposite, compound, without stipules.

Order 216.—*Cyrtandraceæ.* Calyx campanulate, equal. Corolla irregular, imbricated. Stamens didynamous. Disk annular. Ovary 1-celled, with 2 double placentæ; stigma 2-lobed. Fruit capsular and siliquose, or succulent, many-seeded. Seeds minute, often with little tails; albumen absent. Herbs. Leaves opposite, often radical. Flowers showy, in umbels.

Alliance 2.—Acanthales. *Flowers usually didynamous. Seeds adhering to hard hook-like processes. Albumen* 0. *Calyx as if in more whorls than one; often enveloped in bracts.*

Order 217.—*Acanthaceæ.* Calyx very much imbricated, persistent. Corolla irregular, 2-lipped. Stamens mostly 2. Ovary in a disk, 2-celled, 2 or many-seeded; stigma 2-lobed. Capsule 2-celled, bursting elastically. Seeds hanging by processes of the placentæ, hard, usually hooked; albumen none. Herbaceous plants or shrubs. Leaves opposite, without stipules. Inflorescence in spikes, racemes, fascicles, or even solitary. Flowers usually opposite placed in bracts.

Alliance 3.—Lentibales. *Flowers unsymmetrical, diandrous. Fruit with a free central placenta. Marsh or water plants.*

Order 218.—*Lentibulaceæ.* Calyx persistent, inferior. Corolla irregular, bilabiate, with a spur. Stamens 2; anthers simple. Ovary 1-celled; stigma bilabiate. Capsule 1-celled. Seeds minute, without albumen. Herbaceous plants. Leaves undivided, or resembling roots, and bearing vesicles. Flowers single, or in spikes.

Alliance 4.—Scrophulales. *Flowers diandrous, or didynamous. Seeds with the embryo in albumen; their stalks never hooked. Fruit capsular; placenta parallel with the axis.*

Order 219.—*Gesneraceæ.* Calyx half superior, valvate. Corolla tubular, with an imbricate æstivation. Anthers cohering with a thick connective. Ovary 1-celled, with two 2-lobed polyspermous placentæ; surrounded by glands; stigma capitate. Embryo in the axis of albumen. Herbaceous plants or undershrubs. Leaves opposite, rugose, without stipules.

Order 220.—*Orobanchaceæ.* Calyx permanent. Corolla irregular. Stamens didynamous. Ovary 1-celled, in a fleshy disk, with 2 or 4 parietal placentæ; stigma 2-lobed. Fruit capsular, many-seeded, enclosed within the withered permanent corolla; seeds very minute; embryo extremely small, in the apex of fleshy albumen. Parasitical brown leafless herbs.

Order 221.—*Scrophulariaceæ.* Calyx tubular, permanent. Corolla irregular. Stamens didynamous or 2. Ovary 2-celled; ovules numerous; stigma 2-lobed. Fruit 2-celled; seeds indefinite or definite, albuminous. Herbs or shrubs with opposite or alternate exstipulate leaves.

Alliance 5.—Solanales. *Flowers symmetrical. Placenta parallel with the axis. Embryo lying in albumen.*

Order 222.—*Solanaceæ*. Calyx persistent, inferior. Corolla regular, or somewhat unequal, plaited. Stamens inserted upon the corolla. Ovary 2-celled; stigma simple. Pericarp with 2, or 4, or many cells. Seeds numerous; embryo in fleshy albumen. Herbaceous plants or shrubs. Leaves alternate, sometimes collateral. Inflorescence often out of the axil; pedicels without bracts.

Order 223.—*Cestraceæ*. Same as Solanaceæ, but corolla valvate, embryo straight, cotyledons foliaceous.

Alliance 6.—Gentianales. *Flowers symmetrical, usually tetrandrous or pentandrous. Placenta perpendicular to the axis. Seeds often winged or comose. Leaves opposite.*

Order 224.—*Gentianaceæ*. Calyx inferior, persistent. Corolla regular, with an imbricated twisted æstivation. Stamens inserted upon the corolla, some of them occasionally abortive. Ovary 1- or 2-celled; stigmas 1 or 2. Capsule or berry many-seeded; the margins of the valves turned inwards. Embryo in the axis of soft albumen. Herbaceous plants. Leaves opposite, entire, without stipules, 3-5-ribbed.

Order 225.—*Spigeliaceæ*. Calyx inferior. Corolla regular, valvate. Stamens 5. Ovary 2-celled; style articulated with it. Fruit 2-celled, 2-valved, the valves turned in at the margin. Seeds several; embryo very minute, in fleshy albumen. Herbaceous plants or under-shrubs. Leaves opposite, with stipules.

Order 226.—*Apocynaceæ*. Calyx persistent. Corolla regular, 5-lobed, contorted. Stamens 5. Filaments distinct. Pollen granular. Ovaries 2, or 1-2-celled, polyspermous. Stigma 1. Fruit double, or single. Seeds with fleshy albumen. Trees or shrubs, usually milky. Leaves opposite, quite entire, often having glands upon the petioles, with no stipules.

Order 227.—*Asclepiadaceæ*. Calyx persistent. Corolla 5-lobed, regular, imbricated, very seldom valvular. Stamens 5. Filaments connate. Anthers 2-celled. Pollen cohering in masses, and sticking to 5 processes of the stigma. Ovaries 2. Styles 2. Stigma common to both styles, 5-cornered. Follicles 2. Seeds comose; albumen thin. Shrubs or herbaceous plants, milky, and often twining. Leaves entire, opposite, having ciliæ between their petioles.

Alliance 7.—Loganiales. *Flowers unsymmetrical. Stamens never* 2. *Leaves always opposite.*

Order 228.—*Loganiaceæ*. Calyx 5-parted. Corolla regular or irregular, convolute. Stamens all upon the same line, 5-1. Stigma simple. Fruit either capsular with placentæ becoming loose; or drupaceous. Seeds peltate, some times winged; albumen fleshy or cartilaginous. Shrubs, herbaceous plants, or trees. Leaves opposite, usually with stipules in the form of interpetiolary sheaths.

Order 229.—*Potaliaceæ*. Calyx with 4, 5, or 6 partitions. Corolla regular, with 5 to 10 divisions; æstivation contorted. Stamens all upon the same line. Stigma simple. Fruit succulent, with from 2 to 4 cells. Seeds numerous, peltate: embryo in cartilaginous albumen. Trees or shrubs, quite smooth. Leaves opposite, united by interpetiolar stipules.

Alliance 8.—Oleales. *Flowers regular, unsymmetrical, diandrous.*

Order 230.—*Oleaceæ*. Calyx monophyllous, persistent. Corolla hypogynous, 4-cleft, valvate. Stamens 2. Ovary without any disk, 2-celled; ovules pendulous; stigma bifid or undivided. Fruit often by abortion, 1-seeded. Seeds with dense albumen. Trees or shrubs. Branches usually dichotomous. Leaves opposite.

Order 231.—*Jasminaceæ*. Calyx divided or toothed, persistent. Corolla regular, with from 5 to 8 divisions, imbricated and twisted. Stamens 2. Ovary destitute of a disk, 2-celled; ovules erect; stigma 2-lobed. Seeds with no albumen. Shrubs. Leaves opposite or alternate, mostly compound.

Class II.—GYMNOSPERMS.

Exogens, with their ovules exposed naked to the fertilizing influence of the pollen.

Order 232.—*Gnetaceæ.* Flowers monœcious or diœcious, in catkins or heads. Males; calyx 1-leaved; filament simple or branched; one or several anthers, opening by a pore. Females naked; ovary perforated at the apex, containing a solitary erect ovule, pointed by a style-like process. Fruit drupaceous. Pericarp leathery or shelly. Embryo dicotyledonous, in the middle of fleshy albumen. Small trees, or sarmentose shrubs, with thickened separable articulations. Leaves opposite, entire, with pinnate veins, sometimes very minute. Ligneous tissue marked with circular disks.

Order 233.—*Cycadaceæ.* Flowers diœcious. Males monandrous, in cones. Females either in cones, or in the form of contracted leaves. Ovules solitary, naked. Embryo in the midst of albumen. Trees, with a cylindrical trunk, increasing by a single terminal bud. Leaves pinnated, gyrate.

Order 234.—*Pinaceæ,* or *Coniferæ.* Flowers monœcious or diœcious. Males monandrous or monadelphous, collected in a deciduous amentum. Females in cones. Ovary a flat scale. Ovule naked. Fruit a cone. Seed with a hard integument. Embryo in oily albumen, with 2 or many opposite cotyledons. Trees or shrubs, with a branched trunk abounding in resin. Ligneous tissue marked with circular disks. Leaves entire.

Order 235.—*Taxaceæ.* Flowers monœcious or diœcious, solitary. Filaments monadelphous. Females; ovules naked, their outer skin becoming hard. Seed hard, either naked or surrounded by a succulent cup. Albumen fleshy. Embryo dicotyledonous. Trees with continuous branches. Ligneous tissue marked with circular disks. Leaves usually entire; sometimes dilated and lobed, and in those cases having forked veins.

Order 236.—*Equisetaceæ.* Inflorescence consisting of peltate scales. Flowers in the inside of the lobes of the scales. Stamens 4, clavate, wrapped round a naked ovule. Leafless branched plants with a striated fistular stem; the articulations separable and surrounded by a toothed sheath. Spiral vessels very few.

Class III. ENDOGENS, OR MONOCOTYLEDONS.

Elementary organs consisting of both cellular and vascular tissue, a portion of the latter being elastic spiral vessels. Trunk increasing in diameter by the addition of new matter to the centre. Leaves not readily separated from the stem by an articulation, with parallel simple veins, connected by smaller transverse ones. Propagation effected by stamens and pistils. Ovules in a pericarp. Embryo with but 1 cotyledon; if 2, then one imperfect, and alternate with the other.

Group 1. Epigynosae.

Anthers distinct. Flowers complete, ternary. Ovary inferior; or if superior, then the leaves either scurfy or equitant.

Alliance 1.—Amomales. *Leaves with the veins diverging from the midrib to the margin.*

Order 237.—*Zingiberaceæ* or *Scitamineæ.* Calyx superior, tubular. Corolla irregular, with 6 segments in 2 whorls. Stamens 3, of which the 2 lateral are abortive. Filament not petaloid. Anther 2-celled. Stigma dilated, hollow. Fruit usually capsular, occasionally berried. Seeds with or without an aril; albumen floury; embryo enclosed within a vitellus. Aromatic, tropical, herbaceous plants.

Order 238.—*Marantaceæ.* Calyx superior, of 3 sepals. Corolla irregular, with the segments in 2 whorls. Stamens 3, petaloid, of which one of the laterals and

the intermediate are barren or abortive. Filament petaloid. Anther 1-celled. Stigma cucullate, and incurved. Seeds without aril; albumen hard; embryo naked. Herbaceous tropical plants destitute of aroma.

Order 239.—*Musaceæ.* Flowers spathaceous. Perianth 6-parted, petaloid, in 2 rows. Stamens 6, some abortive; anthers 2-celled. Stigma usually 3-lobed. Fruit either a 3-celled capsule, or succulent. Embryo in the axis of mealy albumen. Leaves sheathing at the base, and forming a kind of spurious stem; often very large.

Alliance 2.—Narcissales. *Flowers hexandrous. Sepals and petals petaloid. Leaves never scurfy; with the veins running parallel from the base to the apex.*

Order 240.—*Amaryllidaceæ.* Calyx and corolla regular, colored. Stamens 6; anthers bursting inwardly. Stigma 3-lobed. Albumen fleshy or corneous. Generally bulbous, sometimes fibrous-rooted, occasionally with a cylindrical stem. Leaves ensiform.

Order 241.—*Hæmodoraceæ.* Calyx and corolla more or less woolly. Stamens either 3 and opposite the petals, or 6; anthers bursting inwardly. Stigma undivided. Fruit somewhat nucamentaceous. Leaves equitant.

Order 242.—*Burmanniaceæ.* Perianth tubular, membranous, with 6 teeth the 3 outer, and wing or keel at the back. Stamens 3; anthers sessile, opening transversely. Stigma 3-lobed, petaloid. Capsule covered by the withered perianth. Seeds very numerous, minute. Herbaceous plants, with tufted radical acute leaves, or none; and terminal flowers, sessile upon a 2 or 3-branched rachis, or solitary.

Order 243.—*Taccaceæ.* Perianth with the limb petaloid, equal or unequal. Stamens 6; filaments hooded at the apex; anthers inserted below the points of their filaments. Ovary of 3 connate carpels, with 3 parietal polyspermous placentæ; styles 3, connate; stigmas radiating, 2-lobed. Pericarp 1-celled, many-seeded. Albumen fleshy. Embryo on the outside of the albumen. Large perennial herbs, with a tuberous root. Leaves pedatifid. Flowers on the top of a scape.

Alliance 3.—Ixiales. *Stamens* 3, *with the anthers turned outwards.*

Order 244.—*Iridaceæ.* Calyx and corolla confounded, sometimes irregular. Stamens 3, from the base of the sepals; anthers bursting externally. Stigmas 3, often petaloid. Albumen corneous, or densely fleshy. Herbaceous plants, or undershrubs. Roots tuberous or fibrous. Leaves equitant.

Alliance 4.—Bromeliales. *Calyx usually calycine, sometimes petaline. Petals petaline. Stamens* 6 *or more. Albumen mealy.*

Order 245.—*Bromeliaceæ.* Calyx 3-parted, usually herbaceous. Petals coloured. Stamens 6, or more. Stigma 3-lobed, or entire, often twisted. Seeds numerous; embryo taper, or minute, in the base of mealy albumen. Stemless or short-stemmed plants, with rigid channelled leaves often covered with cuticular scales.

Alliance 5.—Hydrales. *Calyx calycine, Petals petaline. Stamens more than* 6. *Albumen absent.*

Order 246.—*Hydrocharaceæ.* Sepals 3, herbaceous. Petals 3, coloured. Stamens definite or indefinite. Ovary 1 or many-celled; stigmas 3-6; ovules often parietal. Seeds without albumen; embryo undivided, antitropous. Floating or water-plants.

Group 2. Gynandrosae.

Stamens and style consolidated into a column. Flowers complete, ternary. Ovary inferior.

Order 247.—*Orchidaceæ.* Sepals 3. Petals 3, of which 2 are uppermost, and 1, the lip, undermost. Stamens 3, united in a column, the 2 lateral abortive, the central perfect, or the central abortive, and the 2 lateral perfect; pollen powdery, or cohering in masses. Ovary 1-celled with 3 parietal placentæ;

style a part of the column of the stamens ; stigma a viscid space in front of the column. Capsule bursting with 3 or 6 valves. Seeds very numerous ; testa loose, reticulated. Herbaceous plants. Leaves often articulated with the stem.

Order 248.—*Vanillaceæ.* Perianth articulated with the ovary, sometimes with an external calycine cup. Sepals 3, of which 1 forms a lip. Stamen 1, pollen granular. Ovary 1-celled, with 3 parietal placentæ. Fruit succulent. Seeds with a smooth testa tightly adhering to them. Herbaceous plants, with broad leaves; stem mostly climbing.

Order 249.—*Apostasiaceæ.* Calyx and corolla of 3 similar pieces. Anthers 2 or 3, upon a short column. Ovary 3-celled, with 3 polyspermous placentæ in the axis ; style filiform, with a slightly 3-lobed stigma. Capsule 3-celled, 3-valved. Seeds very minute, with a skin fitting the nucleus, or scobiform. Perennial herbaceous plants. Leaves firm, thin, sheathing at the base.

Group 3. Hypogynosae.

Flowers colored, in all cases ternary. Ovary superior.

Alliance 1.—Palmales. *Arborescent plants, with stems growing by the development of a central bud; rarely dichotomous. Embryo in no certain position.*

Order 250.—*Palmaceæ.* Flowers hermaphrodite, or polygamous. Perianth 6-parted, persistent. Stamens inserted into the base of the perianth, definite or indefinite. Ovary 3-celled, or deeply 3-lobed, with an erect ovule. Fruit baccate or drupaceous, with fibrous flesh. Albumen cartilaginous; embryo in a cavity at a distance from the hilum. Leaves terminal, very large, pinnate, or flabelliform, plaited in vernation. Spadix enclosed in a valved spatha. Flowers small.

Alliance 2.—Liliales. *Calyx and corolla distinct, both petaloid. Embryo in the axis of albumen.*

Order 251.—*Pontederaceæ.* Perianth tubular, more or less irregular, with a circinate æstivation. Stamens 3 or 6, unequal. Ovary 3-celled, many-seeded ; stigma simple. Embryo in the axis of mealy albumen. Aquatic or marsh-plants. Leaves sheathing at the base.

Order 252.—*Melanthaceæ.* Perianth in 6 pieces, or tubular ; generally involute. Stamens 6 ; anthers turned inwards. Ovary 3-celled, many-seeded ; style trifid or 3-parted. Capsule divisible into 3 pieces. Albumen dense, fleshy. Roots fibrous, sometimes fascicled. Rhizoma sometimes fleshy. Leaves sheathing at the base.

Order 253.—*Gilliesiaceæ.* Flowers hermaphrodite, surrounded by bracts. Perianth either a single lobe, or an urceolate 6-toothed body. Stamens 6, all fertile, or 3 sterile. Ovary 3-celled ; stigma simple. Capsule 3-celled, many-seeded. Seeds with a broad hollow neck ; embryo curved in the midst of fleshy albumen. Small herbaceous plants. Flowers inconspicuous.

Order 254.—*Liliaceæ.* Calyx and corolla colored, regular. Stamens 6. Anthers opening inwards. Ovary 3-celled; stigma simple, or 3-lobed. Fruit 3-celled. Embryo in the axis of fleshy albumen. Roots fibrous, or fasciculate. Stem none ; a bulb ; or tuberous, or creeping, or arborescent.

Alliance 3.—Commelales. *Sepals leafy. Petals colored. Carpels* 3, *completely combined.*

Order 255.—*Commelinaceæ.* Sepals 3, herbaceous. Petals colored, sometimes cohering at the base. Stamens hypogynous, some deformed. Ovary 3-celled ; stigma 1. Capsule 2- or 3-celled. Seeds often twin ; embryo pulley-shaped, in a cavity remote from the hilum ; albumen fleshy. Herbaceous plants. Leaves usually sheathing.

Alliance 4.—Alismales. *Sepals usually herbaceous. Petals colored. Carpels more or less distinct. Albumen* 0.

Order 256.—*Butomaceæ.* Sepals 3, herbaceous. Petals 3, colored. Stamens definite or indefinite. Ovaries 3, 6, or more. Follicles many-seeded. Seeds

minute, attached to the whole of the inner surface of the fruit. Aquatic plants. Leaves very cellular, often milky.

Order 257.—*Alismaceæ.* Sepals 3, herbaceous. Petals 3, petaloid. Stamens definite or indefinite. Ovaries several, 1-celled; ovules ascending. Fruit not opening, 1 or 2-seeded. Embryo shaped like a horse-shoe. Floating plants.

Alliance 5.—Juncales. *Flowers somewhat glumaceous.*

Order 258.—*Juncaceæ.* Flowers hermaphrodite or unisexual. Calyx and corolla more or less glumaceous. Stamens 6, sometimes 3. Ovary 1- or 3-celled. Stigmas generally 3. Fruit capsular, with 3 valves. Seeds neither black nor crustaceous; albumen firm; embryo within it. Herbaceous plants, with fascicled or fibrous roots. Flowers generally brown or green.

Order 259.—*Philydraceæ.* Perianth 2-leaved, withering. Filaments 3, united at the base; the lateral ones petaloid and sterile; anther with distinct cells. Stigma capitate. Capsule 3-celled, 3-valved. Seeds numerous, minute. Root fascicled, fibrous. Leaves ensiform, equitant. Flowers alternate, solitary, sessile, subtended by a spathaceous bract.

Group 4. Retosae.

Leaves either with many ribs, the intervals between which are netted, or with a midrib and netted sides; foot-stalk articulated with the stem. Embryo without a lateral slit. Flowers never arranged in a spadix. Floral envelopes complete. Twiners or climbers.

Order 260.—*Smilaceæ.* Flowers hermaphrodite or diœcious. Calyx and corolla inferior, 6-parted. Stamens 6, seldom hypogynous. Ovary 3-celled; stigmas 3. Fruit a roundish berry. Albumen between fleshy and cartilaginous. Herbaceous plants or under-shrubs, with a tendency to climb. Stems woody.

Order 261.—*Dioscoreaceæ.* Flowers diœcious. Calyx and corolla superior. Stamens 6. Ovary 3-celled, with 1- or 2-seeded cells; style deeply trifid. Fruit leafy, compressed, occasionally succulent. Embryo small, near the hilum, in a large cavity of cartilaginous albumen. Twining shrubs. Leaves alternate, occasionally opposite.

Order 262.—*Roxburghiaceæ.* Perianth of from 4 to 6 petaloid divisions. Stamens 4 to 6; anthers opening inwards. Ovary superior, 1-celled, with polyspermous placentæ; stigma capitate. Pericarp 1-celled. Seeds with an embryo in the axis of fleshy albumen. Twining shrubs. Flowers large and showy.

Group 5. Spadicosae.

Flowers imperfect, with scales in the room of calyx and corolla, or naked; in most cases on a spadix within a spathe. Embryo usually with a lateral cleft.

Alliance 1.—Pandales. *Flowers on a spadix. Fruit drupaceous. Leaves rigid and with parallel veins. Stem usually arborescent.*

Order 263.—*Pandanaceæ.* Flowers diœcious or polygamous, on a wholly covered spadix. Perianth wanting. Filaments with single anthers. Ovaries collected in parcels, 1-celled; stigmas sessile; ovules solitary, erect. Fruit drupes, or berries. Albumen fleshy; embryo not slit. Stem arborescent, usually sending down aërial roots. Leaves imbricated in three rows, with their margins almost always spiny.

Order 264.—*Cyclanthaceæ.* Flowers monœcious or polygamous, spirally arranged. Males consisting of 2 anthers opening longitudinally in 4 lines. Ovaries with a parietal placentà. Fruit berried. Leaves plaited, petiolate. Spathes membranous and colored.

Alliance 2.—Arales. *Flowers on a spadix. Fruit berried or capsular.*

Order 265.—*Araceæ.* Flowers unisexual. Perianth wanting. Stamens definite or indefinite, very short. Ovary 1-celled, very seldom 3-celled; ovules erect, or pendulous, or parietal; stigma sessile. Fruit succulent. Embryo in the axis of albumen, with a cleft in one side. Herbaceous, or shrubby; stemless or arbo-

rescent. Leaves with parallel or branching veins; sometimes compound. Spadix generally enclosed in a spathe.

Order 266.—*Acoraceæ.* Flowers hermaphrodite, surrounded with scales. Spathe leaf-like. Stamens with 2-celled anthers, turned inwards. Ovaries distinct. Fruit finally juiceless. Seeds albuminous. Rhizoma jointed. Leaves ensiform.

Alliance 3.—Typhales. *Flowers on a spadix. Anthers elevate on long filaments. Sepals of the females either* 3, *or a ring of long hairs.*

Order 267.—*Typhaceæ.* Flowers unisexual upon a naked spadix. Sepals 3, sometimes a bundle of hairs. Petals wanting. Stamens 3 or 6; anthers wedge-shaped. Ovary single, 1-celled; ovule pendulous; stigmas 1 or 2, linear. Fruit not opening. Embryo in the centre of albumen, with a cleft in one side. Herbaceous plants, growing in marshes or ditches. Leaves rigid, ensiform.

Alliance 4.—Fluviales. *Flowers in loose spikes, or solitary.*

Order 268.—*Naiadaceæ* or *Fluviales.* Flowers hermaphrodite or unisexual. Perianth of 2 or 4 pieces, rarely wanting. Stamens definite. Ovaries 1 or more; ovule pendulous. Fruit not opening, 1-celled, 1-seeded. Albumen none; embryo antitropous, with a lateral cleft. Water-plants. Leaves very cellular. Flowers inconspicuous.

Order 269.—*Juncaginaceæ.* Sepals and petals both herbaceous, rarely absent. Stamens 6. Ovaries 3 or 6, cohering firmly; ovules 1 or 2, erect. Fruit dry; albumen wanting; embryo orthotropous, with a lateral cleft. Herbaceous bog-plants. Leaves ensiform. Flowers inconspicuous.

Order 270.—*Pistiaceæ.* Flowers 2, naked. Stamens definite. Ovary 1-celled, with erect ovules. Fruit membranous or capsular, 1 or more seeded. Embryo either in the axis of fleshy albumen, and having a lateral cleft, or at the apex of the nucleus. Floating plants, with very cellular, lenticular, or lobed stems and leaves. Flowers from the margin of the stems.

Group 6. Glumosae.

Perianth usually 0, in its room herbaceous or scarious bracts, imbricated over each other; if present surrounded by such bracts.

Order 271.—*Graminaceæ.* Flowers consisting of imbricated bracts. Glumes usually 2, alternate. Paleæ 2, alternate. Scales 2 or 3, sometimes wanting. Stamens hypogynous, 1, 2, 3, 4, 6, or more; anthers versatile. Ovary simple; styles 2, very rarely 1 or 3; stigmas feathery. Pericarp membranous. Albumen farinaceous; embryo on one side of the albumen, lenticular. Culms cylindrical, usually fistular. Leaves alternate, with a split sheath. Flowers in little locustæ.

Order 272.—*Cyperaceæ.* Flowers consisting of imbricated solitary bracts. Perianth none. Stamens definite, 1, 2, 3, 4, 5, 6, 7, 10, 12; anthers fixed by their base. Ovary often surrounded by bristles; ovule erect; style single, trifid, or bifid. Nut crustaceous or bony. Embryo lenticular, within the base of the albumen. Leaves with their sheaths entire.

Order 273.—*Desvauxiaceæ.* Perianth 0, except sometimes a 2-valved glume. Stamen 1. Ovaries from 3-18. Fruit as many utricles. Little tufted herbs. Leaves setaceous. Flowers in a terminal spathe.

Order 274.—*Restiaceæ.* Perianth inferior, 2-6-parted. Stamens 2-6; anthers usually unilocular. Ovary 1- or more-celled; cells monospermous; ovules pendulous. Fruit capsular, or nucamentaceous. Embryo lenticular, on the outside of the albumen. Herbaceous plants or under-shrubs. Leaves simple, narrow, or none. Culms protected by sheaths which are slit, and have equitant margins. Flowers in spikes.

Sub-order.—*Eriocauleæ.* Flowers in heads. Calyx membranous and very cellular. Seeds covered with hairs. Aquatic plants with cellular equitant leaves.

Order 275.—*Xyridaceæ.* Calyx glumaceous, 3-leaved. Corolla 3-petalled. Fertile stamens 3, upon the claws of the petals; anthers turned outwards. Style

trifid. Capsule 1-celled, 3-valved, with parietal placentæ. Embryo on the outside of the albumen, at the end most remote from the hilum. Herbaceous plants with fibrous roots. Leaves radical, ensiform, with equitant bases. Flowers in terminal, naked, imbricated heads.

Class IV. RHIZANTHS.

Parasitical fungoid leafless plants. Stem homogeneous. Vascular system present. Flowers propagated by sexes. Seeds consisting of a homogeneous sporuliferous mass.

Order 276.—*Rafflesiaceæ.* Flowers by abortion, diœcious. Perianth superior, 5-parted, imbricated; the throat surrounded by calli. Column adhering to the tube of the perianth; anthers numerous, 2-celled, opening by a vertical aperture. Ovary inferior, 1-celled, with many-seeded parietal placentæ; styles conical. Stemless plants. Flowers solitary, immersed among scales.

Order 277.—*Cytinaceæ.* Flowers monœcious at the top of a stalk covered with scales. Perianth tubular, with a spreading limb. Column fleshy, thickened at the point, covered by anthers. Anthers 8, 2-celled. Ovary inferior, 1-celled, with 8 parietal placentæ. Style simple, joined to the tube of the perianth by septiform processes; stigma capitate, thick.

Order 278.—*Balanophoraceæ.* Flowers monœcious, in dense heads. Calyx deeply 3-parted, equal, spreading. Stamens 1-3, epigynous, with both united filaments and anthers; the latter 3. Ovary inferior, 1-2-celled, 1-2-seeded; ovule pendulous. Style 1; stigma simple, rather convex. Fruit 1-celled, containing spores collected in a bag resembling a seed. Fungus-like plants, parasitical upon roots. Stem naked, or covered by imbricated scales.

Order 279.—*Cynomoriaceæ.* Known from Balanophoraceæ by their stamens being distinct, and the perianth of the male flowers imperfect.

Class V. ACROGENS.

Substance of the plant composed of cellular tissue chiefly; spiral vessels or ducts only present in the highest orders. Stem either increasing by an extension of its point, or by a development in all directions from one common point; not increasing in thickness when once formed. Sexual organs absent. Reproduction taking place by spores, or by a mere dissolution of the utricles of tissue.

Alliance 1.—Filicales, *or* Filices. *Leafy plants producing a rhizoma. Leaves usually coiled up in vernation, with dichotomous veins of equal thickness. Thecæ arising from the veins upon the leaves, pedicellate, with an elastic ring, or sessile and destitute of a ring.*

Order 280.—*Polypodiaceæ.* Thecæ with a vertical, usually incomplete ring; bursting irregularly and transversely.

Order 281.—*Gleicheniaceæ.* Thecæ with a transverse, occasionally oblique ring, nearly sessile, and bursting lengthwise internally.

Order 282.— *Osmundaceæ.* Thecæ with an operculiform ring, or without any; reticulated, striated with rays at the apex; bursting lengthwise, and usually externally.

Order 283.—*Danæaceæ.* Thecæ sessile, without any ring, concrete into multilocular sub-immersed masses, opening at the apex.

Order 284.—*Ophioglossaceæ.* Thecæ single, roundish, coriaceous, opaque, without ring or cellular reticulation, half 2-valved. Vernation straight.

Alliance 2.—Lycopodales. *Stems solid, vascular. Reproductive organs growing on the stem.*

Order 285.—*Lycopodiaceæ.* Moss-like plants, with creeping stems, the axis abounding in annular ducts ; or stemless plants, with erect subulate leaves, and a solid cormus. Organs of reproduction axillary sessile thecæ, containing either minute powdery matter, or sporules, marked at the apex with three minute ridges.

Order 286.—*Marsileaceæ.* Creeping plants. Leaves petiolate and divided, coiled up in vernation. Reproductive organs enclosed in leathery involucres, and of two kinds, the one consisting of sacs containing a body or bodies which germinate, the other of similar sacs containing loose granules. Leaves with veins.

Order 287.—*Salviniaceæ.* Stems rooting and floating. Leaves sessile, imbricated, usually papillose. Receptacles globose, of two forms; some filled with angular corpsucles, others 1-celled, comprehending numerous small stalked many-spored bags.

Alliance 3.—Muscales. *Flowerless plants, with a distinct stem having no vascular system, but frequently furnished with leaves; sporules contained in distinct thecæ. Germinating processes uniting into a heterogeneous body.*

Order 288.—*Bryaceæ,* or *Musci.* Cellular plants, having a distinct axis, covered with minute leaves. Reproductive organs of two kinds, viz.: axillary, cylindrical stalked sacs, containing a multitude of particles emitted upon the application of water ; and thecæ or hollow urn-like cases, covered by a calyptra, closed by a lid, within which are rows of processes, called the peristome; the centre of the thecæ occupied by a columella. Sporules protruding confervoid filaments, which afterwards ramify, and form an axis.

Order 289.—*Andræaceæ.* Branching moss-like plants, with imbricated leaves. Thecæ with a calyptra, splitting longitudinally into four valves. Persistome 0. Spores attached to a central columella.

Order 290.—*Jungermanniaceæ.* Creeping moss-like plants, either with imbricated leaves, or with the leaves and axis all fused into one. Thecæ without an operculum, 4-parted, or 2-4-valved. Spores mixed with claters.

Order 291.—*Marchantiaceæ,* or *Hepaticæ.* Plants composed entirely of cellular tissue, emitting roots from their under-side, and consisting of an axis, bordered by a membranous expansion, which sometimes forms a broad lobed thallus. Reproductive organs consisting of a peltate stalked receptacle, bearing thecæ on its under surface ; or of sessile naked thecæ, immersed, or superficial.

Alliance 4.—Charales. *Vascular system wholly wanting. Germinating processes uniting into a heterogeneous body. Reproductive organs axillary globules. Tissue tubular.*

Order 292.—*Characeæ.* An axis, consisting of parallel tubes. Organs of reproduction, succulent globules, containing filaments and fluid; and axillary nucules, formed of short tubes, twisted spirally.

Alliance 5.—Fungales. *Flowerless leafless plants, with no distinct axis of growth. Sporules lying naked in the substance of the plant. Germinating processes either wholly distinct or confluent in a homogeneous body.*

Order 293.—*Fungaceæ,* or *Fungi.* Plants consisting of cellules, among which filaments are occasionally intermixed, increasing in size by addition to their inside; their outside undergoing no change after its first formation, frequently ephemeral. Sporules lying either loose among the tissue, or enclosed in sporidia.

Order 294.—*Lichenaceæ,* or *Lichenes.* Perennial plants spreading in the form of a lobed thallus. Reproductive matter of two kinds; 1, sporules lying in membranous tubes, immersed in shields; 2, separated cellules of the medullary layer of the thallus.

Order 295.—*Algaceæ,* or *Algæ.* Leafless flowerless plants, with no distinct axis; growing in water, consisting either of simple vesicles, or of articulated filaments, or of lobed fronds. Reproductive matter either wanting or in the joints of the filaments, or in thecæ of various forms. Sporules in germination elongating in two opposite directions.

We shall conclude our observations upon the natural system by explaining to the reader the best method of studying it, and the real nature of the difficulties attendant upon its application to practice.

It is alleged by those who are more anxious to throw impediments in the way of a student, than to facilitate his progress, that the natural system of Botany is essentially so abstruse, that no one except those whose lives are devoted to the science, can hope to understand it. It is asserted, that in regard to the three great classes of Dicotyledons, Monocotyledons, and Acotyledons, there is rarely an opportunity of ascertaining to which a given plant belongs, because it is so seldom that the seed can be procured, or because it is so difficult to examine when obtained; and hence, although, supposing the point to be ascertained, the labour of searching through 295 orders would be reduced to one third, yet that in practice, in consequence of the preliminary difficulty just alluded to, the distinction into three classes is perfectly nugatory. But it has been already shewn that although those three classes are distinguished by differences in their seeds, yet that the seed does not furnish the only distinctions between them, but that they are known equally well by differences in their flowers, leaves, manner of germination, and usual mode of growth; so that instead of any real difficulty in finding the class of a plant because of the minuteness of its characters, there is rather a difficulty in mistaking it, so numerous and obvious are the distinctions.

But supposing the difficulty, thus shewn to be imaginary, really to occur, still the student ought not to be disheartened at the number of the natural orders being so great as 295, for of those a large proportion consists of plants of unfrequent occurrence or of little importance, and the great bulk of the vegetable kingdom is comprehended in comparatively a small number of orders. This is shewn, so far as flowering plants are concerned, by the following table of the number of species contained in each natural order of the British Flora :—

1	Ranunculaceæ	37	(1) 37
2	Berberaceæ	2	
3	Nymphæaceæ	3	
4	Papaveraceæ	} 18	(2) 18
4	Fumariaceæ		
5	Brassicaceæ	70	(3) 70
6	Violaceæ	8	
7	Cistaceæ	6	
8	Droseraceæ	3	
9	Frankeniaceæ	2	
10	Polygalaceæ	2	
11	Malvaceæ	6	
12	Hypericaceæ	11	(4) 11
13	Silenaceæ	23	(5) 23
14	Alsinaceæ	37	(6) 37
15	Linaceæ	5	
16	Tiliaceæ	4	
17	Aceraceæ	2	
18	Geraniaceæ	18	(7) 18
19	Oxalidaceæ	2	
20	Balsaminaceæ	1	
21	Illecebraceæ	5	
22	Tamaricaceæ	1	
23	Portulacaceæ	1	
24	Crassulaceæ	16	(8) 16
25	Saxifragaceæ	28	(9) 28
26	Lythraceæ	3	
27	Rhamnaceæ	2	
28	Aquifoliaceæ	1	
29	Celastraceæ	1	
30	Staphyleaceæ	1	
31	Fabaceæ	74	(10) 74
32	Rosaceæ	84	(11) 84
33	Grossulaceæ	6	
34	Onagraceæ	14	(12) 14
35	Circæaceæ	2	
36	Apiaceæ	66	(13) 66
37	Galiaceæ	21	(14) 21
38	Caprifoliaceæ	8	
39	Cornaceæ	3	
40	Loranthaceæ	1	
41	Vaccinaceæ	4	
42	Ericaceæ	14	(15) 14
43	Pyrolaceæ	6	
44	Campanulaceæ	12	(16) 12
45	Lobeliaceæ	3	
46	Valerianaceæ	7	
47	Dipsaceæ	6	
48	Cichoraceæ	37	(17) 37
49	Asteraceæ	66	(18) 66
50	Cynaraceæ	26	(19) 26
51	Boraginaceæ	24	(20) 24
52	Convolvulaceæ	5	
53	Polemoniaceæ	1	
54	Plantaginaceæ	6	
55	Plumbaginaceæ	4	
56	Oleaceæ	3	
57	Apocynaceæ	2	
58	Gentianaceæ	15	(21) 15
59	Solanaceæ	12	(22) 12
60	Primulaceæ	18	(23) 18
61	Lentibulaceæ	7	
62	Scrophulariaceæ	46	(24) 46
63	Orobanchaceæ	8	
64	Verbenaceæ	1	
65	Lamiaceæ	50	(25) 50
66	Santalaceæ	1	
67	Elæagnaceæ	1	

68 Thymelaceæ	2		
69 Polygonaceæ	24	(26)	24
70 Amarantaceæ	1		
71 Chenopodiaceæ	26	(27)	26
72 Sclerantnaceæ	2		
73 Urticaceæ	7		
74 Resedaceæ	3		
75 Euphorbiaceæ	16	(28)	16
76 Empetraceæ	1		
77 Aristolochiaceæ	2		
78 Ulmaceæ	7		
79 Betulaceæ	4		
80 Salicaceæ	33	(29)	33
81 Corylaceæ	6		
82 Pinaceæ	3		
83 Taxaceæ	2		
84 Myricaceæ	1		
85 Callitrichaceæ	3		
86 Araceæ	1		
87 Acoraceæ	1		
88 Typhaceæ	6		
89 Naiadaceæ	15	(30)	15
90 Pistiaceæ	4		
91 Juncaginaceæ	3		
92 Alismaceæ	6		
93 Hydrocharaceæ	2		
94 Iridaceæ	6		
95 Orchidaceæ	38	(31)	38
96 Melanthaceæ	2		
97 Amaryllidaceæ	5		
98 Liliaceæ	26	(32)	26
99 Dioscoreaceæ	1		
100 Butomaceæ	1		
101 Restiaceæ	1		
102 Juncaceæ	31	(33)	31
103 Cyperaceæ	92	(34)	92
104 Graminaceæ	125	(35)	125
	1394		1265

So that the whole of the British flowering plants is comprchended in 35 natural orders, with the exception of 129 species, which belong to 69 orders.

Dr. Asa Gray has made a similar calculation with reference to the Flora of the United States. He estimates that thirteen sixteenths of North American plants belong to 35 natural orders, in the following proportions:—

Asteraceæ, Cichoraceæ, Cynaraceæ	566
Graminaceæ	330
Cyperaceæ	250
Fabaceæ	236
Rosaceæ	158
Brassicaceæ	136
Scrophulariaceæ	131
Corylaceæ, Salicaceæ, Betulaceæ	120
Lamiaceæ	108
Ericaceæ	108
Ranunculaceæ	107
Apiaceæ	69
Onagraceæ	69
Saxifragaceæ	67
Orchidaceæ	62
Silenaceæ, Alsinaceæ	57
Caprifoliaceæ	53
Euphorbiaceæ	52
Polygonaceæ	57
Gentianaceæ	44
Asclepiadaceæ	43
Galiaceæ, Cinchonaceæ	39
Polemoniaceæ	38
Boraginaceæ	35
Violaceæ	35
Convolvulaceæ	35
Solanaceæ	34
Primulaceæ	31
Pinaceæ, Taxaceæ	31
Chenopodiaceæ	31
Liliaceæ	39
Malvaceæ	28
Juncaceæ	24
Melanthaceæ	24
Polygalaceæ	23

And of these moreover the 9 natural orders at the head of the list include one half of the whole number.

It is therefore obvious that there exists a necessity for the acquaintance with a very small part only of the natural system, in order to possess a knowledge of the systematical relations of the greater part of a given Flora.

The most useful method of becoming familiar with each natural order is to procure some species, no matter which, provided it is typical—generally those belonging to the genus after which the order is named, are the commonest and most characteristic—and to examine and describe it carefully, so as to impress it distinctly upon the mind. Having done this, the student should in the next place compare his description with the account he finds of his plant in the books in his possession; if the two agree, he will of course conclude that he has observed it correctly; but if there should be any discrepancy, he ought then to re-examine his plant, with a view to ascertaining whether he is in error or not. A full acquaintance with the typical species being thus obtained, it will be as well to procure a few other nearly related species and to com-

pare them carefully with the first, for the sake of seeing to what extent a deviation from the organization of the original species takes place in them.

In like manner a second natural order should be studied, then a third, and so on, till several types of structure are made familiar to the mind. If about 30 or 40 different forms are correctly understood upon this plan, the student will possess a key to the systematical arrangement of any European Flora according to natural affinities. He will next proceed to study the distinctive characters of such genera as he meets with in each natural order, and he will find that the facility of examining them will be in proportion to the correctness with which he has possessed himself of the characters proper to the natural orders themselves.

It is only after the student has advanced to this point that he is recommended to engage in the study of the smaller and less important natural orders.

The real difficulties that present themselves to the inexperienced botanist are very different from those which are commonly adduced, and are in fact of precisely the same nature as those which occur in regard to all systematical arrangements whatsoever. They arise out of the very nature of natural history, and are caused by that constant tendency to vary from a typical form, which seems to be an essential property of organic matter. It has already been shewn in this treatise that an exact definition is an impossibility in respect to the distinctions of plants, whether viewed as species, genera, tribes, orders, alliances, or groups; that is to say, that no character can be framed to which an exception may not be produced; or that if particular instances of exactly defined associations of plants can be produced, as of Apiaceæ for instance, the cause of such exceptions to a very general rule may be reasonably referred to the incomplete knowledge of them which we as yet possess; and we are justified by all analogy in anticipating the discovery of exceptions to the characters of all such associations.

For example, the principal part of the genus Rhamnus consists of pentapetalous species; and consequently Rhamnus is stationed among Polypetalous Exogens; but Rhamnus alaternus has no petals, and would therefore be looked upon by a student who attended only to words as an incomplete Exogen. This would necessarily be a source of great embarrassment, and illustrates perfectly the most material difficulty that occurs in systematical Botany. But it is not confined to a natural arrangement; on the contrary, such cases happen quite as frequently in the Linnean artificial arrangement, as is shewn by the same genus Rhamnus. The principal part of this genus consists of species which are hermaphrodite and pentandrous; but Rhamnus catharticus is diœcious. In consequence of the preponderance of pentandrous hermaphroditism, Rhamnus is placed in Pentandria; but if a student meets with Rhamnus catharticus he will naturally search for it in Diœcia, where he will not find it. In both these cases, equally, the position of the exceptional species in a system is necessarily determined by their resemblance to other species, and not by their accordance with the verbal definition of the part of the system in which they are placed.

An English botanist has shewn that these cases occur far more frequently than is supposed, in the popular Linnean system. He has proved that in the British Flora alone there are in fourteen sections of the sexual system, containing 173 genera, no fewer than forty-three exceptions, which is nearly equal to one quarter of the whole; (*Lindley's Introduction to the Natural System of Botany*, ed. 1, p. xiii;) and in like manner an ingenious American Botanist has shewn that out of 274 genera belonging to eighteen Linnean sections, there is about the same proportion (78) of exceptions; that is to say, between one-third and one-fourth of the whole number contains "species which are uniformly or commonly at variance with the class or order to which they are referred: thus presenting a much greater amount of exceptions than can be found in all natural families, not only of the district which the work embraces, but in the whole of North America. A similar analysis, compiled from a general Flora of North America according to this system would, we doubt not, exhibit a much greater proportion of exceptions." (*Asa Gray's Elements of Botany*, p. 309.)

Of such instances as that of Rhamnus there is a large number; many polypetalous orders contain monopetalous and incomplete genera, many monopetalous natural orders contain

polypetalous genera, and some even apetalous, as Primulaceæ; and the groups, alliances and genera are in the same condition. Practically such exceptions are not of importance to the experienced botanist, for he soon ceases to judge of plants by their verbal characters, and forms his opinions of them by their natural resemblance in the mass of their characters to other things with which he is acquainted. He knows, for example, that an apetalous Rhamnus is not the less a Rhamnus from wanting petals, *because in all other respects it corresponds with that polypetalous genus*. But the beginner, or the inexperienced botanist, is in a different position; he has not that previous knowledge to refer to, and he is necessarily embarrassed by such exceptions. As these occur perpetually under whatever point of view plants are systematically arranged, it has been proposed to overcome the difficulties they occasion by a method of investigation purely analytical, from which all idea of combination is excluded; for an explanation of which, see chap. xiii.

Chapter X.

Of Artificial Systems.

The sole object proposed by an artificial system is to enable a person to discover the name of a given plant, if it is already known to naturalists. An artificial system may therefore be compared to a dictionary in which words are arranged according to the correspondence of their initial letters, adjacent words having no necessary agreement, except in commencing with the same letters. Such an arrangement of the words of a language is of the highest utility; because from the immutability of words it is impossible for any person to be misled who knows how to spell; and if the nature of plants were immutable in the same degree, an artificial arrangement would also be of great importance in Botany; but it happens that no certain and unvarying signs can be discovered in the vegetable kingdom, and consequently an artificial arrangement participates in all the inconveniences of a natural arrangement, without offering any advantages in compensation. Hence artificial systems are gradually falling into disuse, and are chiefly employed now by writers for popularity.

There are those who conceive that the whole purpose of a systematical arrangement of objects in natural history is to enable a person to discover readily the name of a particular species; and through that discovery to ascertain what is known of its habits, uses, qualities, and so on. Those who entertain that opinion attach little value to a natural arrangement; for the importance of making a systematical classification coincide with an accordance in structure, manner of growth, use, quality, and so on, is in their estimation an object not worth the trouble it appears to occasion.

Let it not, however, be supposed that those great botanists with whom artificial schemes of classification have originated had any such opinion as this. On the contrary, Linnæus in particular invented his system merely as a temporary expedient for reducing disorder into order, and never contemplated its being retained after the principles of the natural system should be better investigated than they had been in his day; and Jussieu applied his merely to the classification of genera too imperfectly known to be correctly referred to any of the natural orders he had proposed. So that neither of these naturalists, and it is not worth mentioning any others with reference to this subject, contemplated the application of their artificial schemes to other than temporary purposes. They were certainly very far from considering them as anything beyond a convenient means of attaining an important end.

We shall give a brief explanation of that of Jussieu, which is little known, and a larger one of the celebrated sexual system of Linnæus.

Chapter XI.

Of the Artificial System of Jussieu.

At the end of his Genera Plantarum, Jussieu arranged upon an artificial plan all those genera, that, from the imperfect manner in which they had been examined, the incompleteness of their descriptions, or the singularity of their structure, were not capable of being referred to any of his natural orders. Among "methodical indexes," as he called all artificial arrangements, Jussieu considered that the best which is most efficient with the least disturbance of natural affinity, and hence he preferred the great features in the method

of Tournefort, derived from differences in the corolla, to those of Linnæus derived from differences in the sexes. But in regard to secondary characters, he considered the differences taken by Tournefort from the form of the corolla, and from the woody and herbaceous condition of the stem, as unimportant; for which he substituted the position of the ovary with regard to the calyx. He further proposed to subdivide his secondary divisions according to the number, &c., of the stamens; thus forming a combination of the methods of Tournefort and Linnæus with an important addition of his own.

The result of such a combination is the following scheme:—

Class 1.—MONOPETALOUS.

Order 1.—Ovary superior.
Linnean subdivisions.
Order 2.—Ovary inferior.
Linnean subdivisions.

Class 2.—POLYPETALOUS.

Order 1.—Ovary superior.
Linnean subdivisions.
Order 2.—Ovary inferior.
Linnean subdivisions.

Class 3.—APETALOUS, HERMAPHRODITE.

Order 1.—Ovary superior.
Linnean subdivisions.
Order 2.—Ovary inferior.
Linnean subdivisions.

Class 4.—APETALOUS, UNISEXUAL.

Order 1.—Ovary superior.
Linnean subdivisions.
Order 2.—Ovary inferior.
Linnean subdivisions.

It is not a little curious that this scheme, which is in every respect so much superior to that of Linnæus, should have attracted so little notice. For facility of reference, and convenient grouping it is far more useful; as a ready means of sorting plants it is infinitely preferable; and as a method of analysis it has the great advantage of breaking up the vegetable kingdom into a much larger number of subdivisions. The Linnean system does not admit at the most of more than 215 final groups, but this artificial scheme of Jussieu may contain considerably more than 1000. The only mode of accounting for its not having been adopted is upon the supposition that those who studied the work of Jussieu did not recognise the necessity of any artificial method whatsoever, and therefore did not adopt his; while those who preferred an artificial method of classification were either contented with that of Linnæus with all its inconveniences, or were unacquainted with that of Jussieu.

Chapter XII.

Of the Linnean or Sexual System

One of the most remarkable discoveries of Linnæus was the existence in all plants of sexes analogous to those of animals. That some plants have sexes was not indeed any discovery of his, for it was an admitted fact in certain cases long before the time of Linnæus; but it was to him that the world owed the proof that that which had been regarded as a special property of particular kinds of plants was an universal property of vegetable nature. It is not surprising then that when pursuing his investigations of this curious subject, he should have been led to adopt the differences in the number, position, proportion, &c. of the sexual organs as the basis of a system of classification. Neither is it to be wondered at that the world should have been so dazzled by the brilliancy of the discovery of sexes in plants, and the ready adaptation of the discovery to purposes of

arrangement, by one of the most clear-headed and skilful systematists that the world has ever produced, as to have failed to perceive, even after the lapse of more than half a century, how much more specious than solid is the whole framework of the famous sexual system. Little indeed was really known of the extent of the vegetable kingdom for more than seventy years after the artificial system of Linnæus was first promulgated; it had generally been considered with reference chiefly to the inconsiderable Flora of Europe, and often of mere corners of Europe, for the great mass of Linnean systematists has always consisted of the writers or compilers of little local Floras. Hence the inapplicability of it with any kind of convenience to the whole vegetable kingdom was not capable of being appreciated, and the numerous exceptions which its advocates could not conceal or diminish were undervalued, and spoken of as if they were likely to be fewer in countries of a more varied and richer vegetation, rather than incalculably more numerous.

Before proceeding to discuss specifically the advantages and disadvantages of this celebrated system, we shall first explain the system itself. Its classes, twenty-four in number, are exclusively founded upon differences in the number, position, proportion, adhesion, &c. of the stamens; the orders or subordinate divisions upon variations principally of the styles, although peculiarities in the stamens are sometimes also employed in distinguishing orders as well as classes. The characters of the classes are as follows:—

Class	I.	Stamen 1	Monandria.
	II.	Stamens 2	Diandria.
	III.	Stamens 3	Triandria.
	IV.	Stamens 4	Tetrandria.
	V.	Stamens 5	Pentandria.
	VI.	Stamens 6	Hexandria.
	VII.	Stamens 7	Heptandria.
	VIII.	Stamens 8	Octandria.
	IX.	Stamens 9	Enneandria.
	X.	Stamens 10	Decandria.
	XI.	Stamens 12—19	Dodecandria.
	XII.	Stamens 20 or more, inserted into the calyx	Icosandria.
	XIII.	Stamens 20 or more, inserted into the receptacle	Polyandria.
	XIV.	Stamens 2 long and 2 short	Didynamia.
	XV.	Stamens 4 long and 2 short	Tetradynamia.
	XVI.	Stamens united by their filaments into a tube	Monadelphia.
	XVII.	Stamens united by their filaments into two parcels	Diadelphia.
	XVIII.	Stamens united by their filaments into several parcels	Polyadelphia.
	XIX.	Stamens united by their anthers into a tube	Syngenesia.
	XX.	Stamens united with the pistil	Gynandria.
	XXI.	Stamens and pistils in separate flowers, but both growing on the same plant	Monœcia.
	XXII.	Stamens and pistils not only in separate flowers, but those flowers situated upon two different plants	Diœcia.
	XXIII.	Stamens and pistils separate in some flowers, united in others, either on the same plant, or two or three different ones	Polygamia.
	XXIV.	Stamens and pistils either not ascertained, or not to be discovered with any certainty, insomuch that the plants cannot be referred to any of the foregoing classes	Cryptogamia.

The characters of the orders depend upon the number of the styles, or of the stigmas, if there be no style, in the first thirteen classes; such are accordingly named,—

Monogynia	Style	1
Digynia	Styles	2
Trigynia		3
Tetragynia		4
Pentagynia		5
Hexagynia		6
Heptagynia		7

Octogynia	Styles	8
Enneagynia	.	9
Decagynia	.	10
Dodecagynia	.	12
Polygynia	.	more than 12.

In the 14th class, Didynamia, the orders depend upon the nature of the ovary. In *Gymnospermia*, the first order, the ovary is divided into four lobes, from the base of which proceeds a single style, and within each of which is contained a single seed. In *Angiospermia*, the 2nd order, the ovary is not lobed, and is usually two-celled, and many-seeded.

In the 15th class, Tetradynamia, the orders are characterised by the form of the fruit: *Siliquosæ* have a long pod; *Siliculosæ* have a short one.

The orders of the 16th, 17th, and 18th classes, Monadelphia, Diadelphia, and Polyadelphia, depend upon the number of the stamens, and have the same nomenclature as the thirteen first classes.

The orders of Syngenesia are determined by the arrangement of their flowers, and by the sex of their florets: thus—

Polygamia, has flowers crowded together in heads.

1. *Polygamia æqualis*, has each floret hermaphrodite, or furnished with perfect stamens and pistil.

2. *Polygamia superflua*, has the florets of the disk hermaphrodite; those of the ray female only.

3. *Polygamia frustranea*, has the florets of the disk hermaphrodite; those of the ray steril.

4. *Polygamia necessaria*, has the florets of the disk male, of the ray female.

5. *Polygamia segregata*, "has several florets, either simple or compound, but with a proper calyx, included within one common calyx."

Monogamia, has the flowers separate, not crowded in heads. This order is generally abolished by Linnean botanists, but for no good reason.

The orders of the 20th, 21st, and 22nd classes are distinguished by the number, &c. of the stamens;

The two orders of the 23rd class depend upon whether the genera are monœcious or diœcious.

The last class, Cryptogamia, is divided into orders according to the principles of the natural system, namely, 1. Filices; 2. Musci; 3. Hepaticæ; 4. Algæ; 5. Fungi.

Various modifications and alterations of this method have, from time to time, been proposed by different writers; some reducing the whole of Monœcia, Diœcia, and Polygamia to other classes, others combining some of the smaller classes with the larger ones. The late Professor Richard in particular suggested several real improvements; but they now excite so little interest, in consequence of the neglect into which the artificial system has deservedly fallen, that it is not worth enumerating them in this place.

The reader will at once perceive the merits of the sexual system of Linnæus. It is so simple that any body may master it in an hour; the names of its classes and orders generally carry with them their own explanation; the parts upon whose difference the system turns are readily examined; and the whole scheme is so plain as to be intelligible to the meanest capacity. These are its advantages. Its disadvantages much more than counterbalance them.

If it is easy to discover the class and order of a plant in the Linnean system, it is proportionably difficult to ascertain its genus, because each order contains a very large number of genera, usually having no relation to each other, and each of which must consequently form a distinct subject of study. But it is very often impossible to discover even the class and order, because the same genus will comprehend species belonging to different classes and orders, and a genus has only one place in the system; so that it is incorrect to say that the artificial method of Linnæus is the same to Botany as an alphabet is to a language, because it has not and cannot have the same precision. An alphabet is formed upon unerring characters: an artificial system in natural history is necessarily founded upon varying characters. In case the inquirer commits an error in determining the class and order of his plant, he has no means of checking it by taking into account other characters than those by which the class and order are actually settled. Finally, it is necessary to have a plant in flower in order to commence its examination, and it is inconvenient to be compelled to study a plant exclusively in some one state, inasmuch as it must often happen that the plant is not in that state when it is collected.

Upon this subject we have the following additional remarks from Professor Lindley:—

It is now admitted on all hands that the artificial system of Linnæus, which was so important and useful at the time when it was first contrived, is altogether unsuited to the present state of science; and in the latest work that has been published in this country, upon that system, the learned and amiable author is forced to rest his defence of his still following it upon "the facility with which it enables any one, hitherto unpractised in Botany, to arrive at a knowledge of the genus and species of a plant." But if a system of Botany is to be nothing more than a contrivance to help those who will not master the elements of the science, to determine the name of a plant; and if it is really necessary to have a mental rail-road on which such persons may be impelled without any exertion of their own; then indeed the analytical tables of the French are infinitely better contrivances than the sexual system; because if well executed they meet every case and lead with certainty to positive results.

I have, however, been always at issue with the Linnean school of Botany as to their system accomplishing even the little that it pretends to; and if I may be permitted to appeal to my own personal experience of the difficulties of a beginner who is unassisted by a tutor, (and few could have had fewer difficulties to contend against than myself,) I should say that it is totally opposed to such a conclusion. I began with the Linnean system, which I was taught to believe little less than an inspired production; I had plenty of books compiled according to that system to consult, and I was fairly driven to seek refuge in the natural system from the difficulties and inconsistencies of that of Linnæus.

It seems to me that there is a confusion of ideas in what is urged in favour of the Linnean system, and that its theoretical simplicity is mistaken for practical facility of application. That the principles of the Linnean system are clear and simple, and easily remembered, is indisputable; that student indeed must be remarkably dull of apprehension who could not master them in a day. But is its application equally easy? that is the point. When, for example, a specimen of a Monopetalous plant has lost its corolla, or when the stamens or pistils are absent, either accidentally, or constitutionally, as in Diœcious plants, what Linnean botanist can classify the subject of inquiry? Or where a genus comprehends species varying in the number of their stamens, as for instance, Polygonum, Salix, Stellaria, and hundreds of others, who is to say which of the species is to determine the classification of the rest? Or when this point has been settled, how is the student to know what passed in the mind of the botanical systematist? The latter puts a genus into Octandria, because out of ten species, one has constantly, and two occasionally, eight stamens, and he includes in the same class and order all the other species of the genus, although they have five, six, or ten stamens. Suppose the student meets with one of the last, and wishes to ascertain its name by the Linnean system, he will look for it in Pentandria, or Hexandria, or Decandria, where he will not find it. After wasting his time, and exhausting his patience in a vain pursuit, he must abandon the search in utter hopelessness, for there is no other character that he can make use of as a check upon the first. At last some one will tell him that his plant is a Polygonum: he turns to his book, wondering how he could have overlooked it; and he finds Polygonum in Octandria. Should he inquire how this is, he will learn that his species belongs to Octandria, not because it is octandrous, *but because it is so very like other Polygonums, that it cannot be separated from them, and they belong in most cases to Octandria.* This is the unavoidable answer; and what does it really mean, except that it is not in consequence of its accordance with the system that the student's Polygonum is to be discovered, *but in consequence of its natural relation to other Polygonums?* so that it is necessary to understand the natural system to make use of the artificial system! This is no exaggerated case, but one of common occurrence. It is undoubtedly true that in some books such inconvenience is guarded against by special contrivances; but those contrivances form no part of the system.

Granting, however, for argument's sake, that these and other objections are overstated, and that the Linnean system does really facilitate the discovery of the class and order to which a plant belongs, let us next consider what advance towards the determination of the genus and species, or in other words the name of a plant, a student has really made, when the class

and order are ascertained. If this argument were conducted, as in strictness it ought to be, with reference to the whole vegetable kingdom, it would be easy to show that the student had in fact gained almost nothing that was of use to him; but in order to give the friends of the Linnean system every advantage in the discussion, let us see of what use it will be to him in regard to the few hundred plants that grow wild in England. For this purpose take the generic characters in Diandria Monogynia, as stated in Dr. Hooker's British Flora, a work in which the subject is treated with all the skill and perspicuity of which it is susceptible, and in which the Linnean system is seen to the greatest advantage. The characters are these:—

* *Perianth double, inferior, monopetalous, regular.*

1. Ligustrum, *Linn.* Privet.—*Cor.* four-cleft. *Berry* two-celled, with the cells two-seeded.

** *Perianth double, inferior, monopetalous, irregular. Seeds enclosed in a distinct pericarp (Angiospermous).*

2. Veronica, *Linn.* Speedwell.—*Cor.* four-cleft, rotate, lower segment narrower. *Caps.* two-celled.

3. Pinguicula, *Linn.* Butterwort.—*Cal.* two-lipped, upper lip of three, lower of one bifid segment. *Cor.* ringent, spurred. *Germen* globose. *Stigma* large, of two unequal plates or lobes. *Capsule* one-celled, with the seeds attached to a central receptacle.

4. Utricularia, *Linn.* Bladderwort.—*Cal.* two-leaved, equal. *Cor.* personate, spurred. *Stigma* two-lipped. *Caps.* globose, of one cell. *Seeds* fixed to a central receptacle.

*** *Perianth double, inferior, monopetalous, irregular. Seeds four, apparently naked (closely covered by the pericarp. Gymnospermous.)*

5. Lycopus, *Linn.* Gipsey-wort.—*Cal.* tubular, five-cleft. *Cor.* tubular, limb nearly equal, four-cleft, upper segment broader, and notched. *Stam.* distant, simple.

6. Salvia, *Linn.* Sage or Clary.—*Cal.* two-lipped, tubular. *Cor.* labiate, the tube dilated upwards and compressed. *Filaments* with two divaricating branches, one only bearing a perfect single *cell* of an *anther*.

**** *Perianth double, superior.*

7. Circæa, *Linn.* Enchanter's Nightshade.—*Cal.* two-leaved, but united into a short tube at the base. *Cor.* of two petals. *Caps.* two-celled; cells one-seeded.

***** *Perianth single, or none.*

8. Fraxinus, *Linn.* Ash.—*Cal.* 0, or four-cleft. *Cor.* 0, or of four petals. *Caps.* two-celled, two-seeded, compressed and foliaceous at the extremity. *Seeds* solitary, pendulous. (Some flowers without stamens.)

9. Lemna, *Linn.* Duckweed.—*Perianth* single, monophyllous, membranaceous, urceolate. *Fruit* utricular.

10. Cladium, *Schrad.* Twig-rush.—*Perianth* single, glumaceous. *Glumes* of one piece or valve, one-flowered, imbricating; outer ones steril. *Fruit* a nut, with a loose external coat, destitute of bristles at the base.

This extract from the British Flora makes it evident that in determining to what genus a plant belongs a great deal of inquiry beyond the discovery that it has two stamens and one style, is indispensable: "The student must be acquainted with the meaning of many technical terms; he must have his plant in different states of growth; he must procure the fruit; he must examine the interior of that part; in short, he must go through a long and careful examination, which is entirely independent of the sexual system. In other and larger classes, such as Pentandria, Hexandria, Tetradynamia, Syngenesia, Gynandria, and Monœcia, the length and difficulty of such an examination are vastly increased. Now I distinctly assert that there is no difficulty in determining the natural orders of plants greater than that of making out the genera in the Linnean system. In fact it is the very same thing, only with a different result: in the one case it leads to the mere discovery of a name, in the other to the knowledge of a great number of useful and interesting facts, independent of the name."

It is necessary to make these obser-

vations, in consequence of the strong prejudices that people entertain in this country concerning the sexual system, believing it to be the most perfect, the most useful, the most philosophical that has ever been devised for the classification of plants. It is no disrespect to the author of that system, to shew its imperfection and inutility; a philosophical character he never dreamed of claiming for it. An ingenious American botanist has well observed, that no one could be more fully aware of the insufficiency of an artificial system in botany, or could more highly appreciate the advantages of the natural method, than Linnæus himself; and the so-called Linnean botanists, in whose estimate the former system leaves little to be desired, have quite mistaken the views of their great master, and sadly misrepresented his opinions. While he framed an artificial system for the convenient arrangement of plants, justly considering it as the one best adapted for this purpose at that day, and indeed as the only available one in the then existing state of the science; he also gave a sketch of a natural method, explaining the principles on which the latter might be expected to rest, and pronounced the investigation of natural affinities to be the great object of his studies, and the most important part of the science; considering the artificial system as a temporary expedient, which however necessary at that day, would inevitably give place to the system of nature so soon as its fundamental principles should be discovered. It will not be deemed irrelevant to adduce more fully the testimony of Linnæus on this subject; since, in this country at least, the well-deserved fame of that distinguished naturalist is somewhat endangered by the eulogies and injudicious zeal of those who pretend to be his followers and exclusive admirers. Linnæus, with all his partiality for the system he himself invented, affirms that the artificial method is but a substitute for the natural, to which it must in due time give place. The natural method, he also states, is and must be the principal object of the science; the elucidation of which is the first and ultimate aim of botanists: to this end the labour of the greatest botanists should be diligently directed, and the merest fragments of this system should be carefully studied. Though not yet discovered, it is held in high estimation by the wisest botanists, while by the less learned it is thought to be of little consequence. "For a long time," continues Linnæus, "I have laboured to establish it; I have made many discoveries, but have not been able to perfect it; yet while I live I shall continue to labour for its completion. In the mean time I have published what I have been able to discover, and whosoever will resolve the few plants which still remain, shall be my Magnus Apollo. Those are the greatest botanists who are able to correct, augment, and perfect this method; which those who are unqualified should not attempt."

It must now, we think, be conceded on all hands, that the day anticipated by Linnæus has arrived, when the artificial system having effected the object for which it was invented—that of serving as a temporary substitute for a natural system—is no longer needed; that it has, in fact, after accomplishing a great amount of good in its day, given place to another method equally convenient, and infinitely more philosophical as well as useful; and those who perpetuate its existence on account of the alleged facilities which it presents for acquiring a mere knowledge of names, with the least possible expenditure of thought, would do well to consider whether the respect due to the system of Linnæus, viewed in reference to the higher ends for which he himself intended it, be not compromised by permitting its degradation to purposes for which it was not originally designed.

Chapter XIII.

Of Analytical Schemes.

It has already been stated that from the variable nature of organic bodies, there is no possibility of framing exact definitions of the associations into which they are systematically distributed. Moreover, the great number of such associations renders it desirable that some ready means should be devised for analyzing them, and bringing their points of difference into direct contrast.

For this purpose two methods have been devised; one, which may be called *the tabular*, by Ray; the other, which may be termed *the dichotomous*, by Lamarck. These are both founded upon the common process of analysis which is unconsciously employed by the human mind. In all cases the mental operation by which one thing is distinguished from another, consists in a

continual contrasting of characters. For instance, in a mass of individuals we distinguish one set which is coloured, and another which is colourless; of those that are coloured we distinguish red, black, blue, and green; of the red, some are square, others are round; of the round, some are sculptured on their surface, others are even:—and so we proceed, analyzing the subject by a constant series of contrasts, until we have arrived at the point beyond which no analysis can go.

Ray reduced this to a tabular form. Lamarck represented it by a constant succession of dichotomies or divarications connected with each other by means of numbers. We offer an example of each, applied to the natural orders comprehended in the Flora of Great Britain.

Tabular Analysis of the Natural Orders comprehended in the British Flora, according to the method of Ray.

CLASS I. EXOGENS.

Sub-class 1. POLYPETALÆ.

* Polyandrous. *Stamens more than* 20.

§ *Ovary inferior, or partially so.*

- Leaves with stipules . . . . . Pomeæ.
- Leaves without stipules . . . . Nymphæaceæ.

§§ *Ovary wholly superior.*

- Leaves with stipules.
  - Carpels more or less distinct, or solitary . . . Rosaceæ.
  - Carpels wholly combined into a solid pistil with more placentas than one.
    - Calyx imbricated . . . . . Cistaceæ.
    - Calyx valvate.
      - Stamens monadelphous . . . . Malvaceæ.
      - Stamens distinct . . . . . . Tiliaceæ.
- Leaves without stipules.
  - Carpels more or less distinct.
    - Stamens perigynous . . . . . Rosaceæ.
    - Stamens hypogynous.
      - Calyx in a perfect whorl . . . . Ranunculaceæ.
      - Calyx in a broken whorl . . . . Hypericaceæ.
  - Carpels wholly combined.
    - Placentas parietal . . . . Papaveraceæ.
    - Placentas spread over the dissepiments . . Nymphæaceæ.
    - Placentas in the axis . . . . . Cistaceæ.

** Oligandrous. *Stamens fewer than* 20.

§ *Ovary inferior, or partially so.*

- Placentas parietal.
  - Flowers unisexual . . . . . Cucurbitaceæ.
  - Flowers hermaphrodite . . . . . Grossulaceæ.
- Placentas in the axis.
  - Flowers in umbels . . . . . Apiaceæ.
  - Flowers not in umbels.
    - Fruit many-seeded,
      - two-celled . . . . . . Saxifragaceæ.
      - four-celled . . . . . . Onagraceæ.
    - Fruit few-seeded . . . . . Cornaceæ.

§§ Ovary wholly superior.

† Leaves furnished mith stipules.

Carpels distinct.
  Fruit leguminous . . . . . . Fabaceæ.
  Fruit drupaceous or capsular . . . . Rosaceæ.
Carpels combined.
  Placentas parietal.
    Leaves circinate when young . . . . Droseraceæ.
    Leaves straight when young . . . . Violaceæ.
  Placentas in the axis.
    Styles distinct to the base.
      Calyx in a broken whorl . . . . Elatinaceæ.
      Calyx in a perfect whorl.
        Petals minute . . . . . Illecebraceæ.
        Petals conspicuous . . . . . Saxifragaceæ.
    Styles more or less combined.
      Gynobasic.
        Fruit beaked . . . . . Geraniaceæ.
        Fruit not beaked . . . . Oxalidaceæ.
      Not Gynobasic.
        Calyx imbricated . . . . Portulacaceæ.
        Calyx valvate . . . . . Rhamnaceæ.

†† Leaves without stipules.

Carpels distinct.
  Anthers with recurved valves . . . . Berberaceæ.
  Anthers with longitudinal valves.
    Carpels each with an hypogynous scale . . Crassulaceæ.
    Carpels without an hypogynous scale . . . Ranunculaceæ.
Carpels combined.
  Stamens tetradynamous . . . . . Brassicaceæ.
  Stamens not tetradynamous.
    Placentas parietal.
      Calyx polysepalous.
        Albumen large . . . . . Papaveraceæ.
        Albumen none . . . . . Resedaceæ.
      Calyx tubular . . . . . Frankeniaceæ.
    Placentas in the axis.
      Styles distinct to the base.
        Calyx in a broken whorl.
          Stamens polyadelphous . . . . Hypericaceæ.
          Stamens monadelphous or free . . Linaceæ.
        Calyx in a perfect whorl.
          Carpels divaricating at the apex . . . Saxifragaceæ.
          Carpels not divaricating.
            Calyx tubular . . . . Silenaceæ.
            Calyx many-leaved . . . . Alsinaceæ.
      Styles more or less combined.
        Calyx in a broken whorl.
          regular . . . . . Aceraceæ.
          papilionaceous . . . . . Polygalaceæ.
        Calyx in a perfect whorl.
          Anthers opening by pores . . . Ericaceæ.
          Anthers opening by slits.
            Flowers unisexual . . . . . Empetraceæ.
            Flowers hermaphrodite.
              Calyx tubular . . . . Lythraceæ.
              Calyx many-leaved.
                Stamens hypogynous.
                  Brown parasites . . . Monotropaceæ.
                  Green shrubs . . . . Tamaricaceæ.
                Stamens perigynous . . . Celastraceæ.

Sub-class II. INCOMPLETÆ.

** Achlamydeous. Neither calyx nor corolla.*

Seeds comose	Salicaceæ.
Seeds naked.	
Fruit tricoceous	Euphorbiaceæ.
Fruit indehiscent.	
Flowers amentaceous	Myricaceæ.
Flowers solitary	Callitrichaceæ.
Flowers panicled	Oleaceæ.

*** Monochlamydeous. A calyx present.*

§ Ovary inferior, or nearly so.

lowers unisexual.	
Fruit in a cupule	Corylaceæ.
Fruit naked	Cucurbitaceæ.
Flowers hermaphrodite.	
Ovary one-celled. Anther two-celled.	
Embryo straight.	
Albumen none	Halorageæ.
Albumen fleshy	Santalaceæ.
Embryo curved	Chenopodiaceæ.
Ovary one-celled. Anthers many-celled	Loranthaceæ.
Ovary more than one-celled	Halorageæ.

§§ Ovary superior.

Leaves with stipules.	
Flowers hermaphrodite.	
Carpels two, combined into a solid pistil	Ulmaceæ.
Carpels solitary or quite separate.	
Calyx membranous	Illecebraceæ.
Calyx firm and herbaceous.	
Styles single	Sanguisorbaceæ.
Styles triple	Polygonaceæ.
Flowers unisexual.	
Carpels more than one.	
Flowers amentaceous	Betulaceæ.
Flowers not amentaceous	Euphorbiaceæ.
Carpels solitary	Urticaceæ.
Leaves destitute of stipules.	
Flowers unisexual	Euphorbiaceæ.
Flowers hermaphrodite.	
Carpels more than one, consolidated.	
Two divaricating carpels	Saxifragaceæ.
Carpels not divaricating.	
Stamens hypogynous	Alsinaceæ.
Stamens perigynous.	
Fruit one-celled	Primulaceæ.
Fruit many-celled	Lythraceæ.
Carpels solitary, or separate	
Carpels several	Ranunculaceæ.
Carpels solitary.	
Calyx with a hardened tube	Scleranthaceæ.
Calyx herbaceous.	
Stipules ochreate	Polygonaceæ.
Stipules 0.	
Ovules pendulous	Thymelaceæ.
Ovule erect.	
Leaves lepidote	Elæagnaceæ.
Leaves naked	Chenopodiaceæ.

Sub-class III. MONOPETALÆ.

* *Ovary superior. Flowers regular.*

Ovary four-lobed . . . . Boraginaceæ.
Ovary entire.
Carpels 4, 5, or more.
Anthers opening by pores.
Herbs . . . . . . Pyrolaceæ.
Shrubs . . . . . . Ericaceæ.
Anthers opening by slits.
Stamens opposite the segments of the corolla and equal to them in number . . . Primulaceæ.
Stamens not opposite the segments of the corolla, if the same number.
Seeds indefinite . . . . . Crassulaceæ.
Seeds definite in number.
Ovules erect . . . . Convolvulaceæ.
Ovules pendulous . . . . Aquifoliaceæ.
Carpels usually three . . . Polemoniaceæ.
Carpels only two.
Diandrous . . . . . Oleaceæ.
Stamens 4 or more.
Calyx in a broken whorl.
Leafy twiners . . . . Convolvulaceæ.
Leafless twining parasites . . . Cuscutaceæ.
Calyx in a perfect whorl.
Carpels ⊃ . . . . . Solanaceæ.
Carpels ( )
Corolla imbricated . . . . Gentianaceæ.
Corolla contorted . . . . Apocynaceæ.
Carpel single.
Style single . . . . . . Plantaginaceæ.
Styles 5 . . . . . . Plumbaginaceæ.

** *Ovary superior. Flowers irregular.*

Ovary four-lobed . . . . . Lamiaceæ.
Ovary entire.
Fruit nucamentaceous . . . . Verbenaceæ.
Fruit capsular.
Capsule, two-celled
Leafy . . . . . . Scrophulariaceæ.
Brown leafless parasites . . . Orobanchaceæ.
Capsule, one-celled, with a free central placenta . Lentibulaceæ.

*** *Ovary inferior.*

Carpel solitary.
Anthers syngenesious . . . . Asterales.
Anthers free.
Carpel quite solitary . . . . . Dipsaceæ.
Carpel with two additional abortive ones . . Valerianaceæ.
Carpels more than one.
Anthers syngenesious . . . . Lobeliaceæ.
Anthers free.
Anthers opening by pores . . . . Vaccinaceæ.
Anthers opening by slits.
Seeds indefinite . . . . Campanulaceæ.
Seeds definite.
Leaves whorled . . . . . Galiaceæ.
Leaves opposite . . . . Caprifoliaceæ.

CLASS II. GYMNOSPERMS.

Stems without articulations.
  Fruit single . . . . . . Taxaceæ.
  Fruit in cones . . . . . . Pinaceæ.
Stems articulated . . . . . Equisetaceæ.

CLASS III. ENDOGENS.

* Flowers complete.

§ *Ovary inferior.*

Flowers gynandrous . . . . . Orchidaceæ.
Flowers not gynandrous.
  Stamens 3 . . . . . . Iridaceæ.
  Stamens 6 . . . . . . Amaryllidaceæ.
  Stamens more than 6 . . . . . Hydrocharaceæ.

§§ *Ovary superior.*

Sepals calycine or glumaceous.
  Carpels consolidated . . . . . Juncaceæ.
  Carpels separate . . . . . Alismaceæ.
Sepals corolline.
  Carpels separate.
    Anthers turned outwards . . . . Melanthaceæ.
    Anthers turned inwards . . . . Butomaceæ.
  Carpels consolidated . . . . . Liliaceæ.

** Flowers incomplete.

Flowers glumaceous.
  Stems hollow . . . . . . Graminaceæ.
  Stems solid.
    Seed erect . . . . . . Cyperaceæ.
    Seed pendulous . . . . . Restiaceæ.
Flowers naked, or with a few verticillate scales, on a spadix.
  Anthers clavate on weak filaments . . . . Typhaceæ.
  Anthers sessile.
    Gemmation convolute . . . . . Araceæ.
    Gemmation equitant . . . . . Acoraceæ.
Flowers naked, or with a few verticillate scales, not on a spadix.
  Floaters. Ovules pendulous . . . . Naiadaceæ.
  Terrestrial. Ovules erect . . . . . Juncaginaceæ.
  Floaters. Ovules erect . . . . . Pistiaceæ.

CLASS IV. RHIZANTHS.

There are none in Great Britain.

CLASS V. ACROGENS.

With a distinct axis of growth; leafy.
  Thecæ seated on the leaves . . . . Filicales.
  Thecæ axillary.
    Thecæ sessile, two-valved . . . Lycopodiaceæ.
    Thecæ stalked or valveless.
      Thecæ valveless, with an operculum . . . Bryaceæ.
      Thecæ valvate, with an operculum . . Andreaceæ.
      Thecæ valvate, without an operculum . . . Jungermanniaceæ.
With a distinct axis of growth; leafless . . . Characeæ.
Without a distinct axis of growth.
  Surface with stomates.

Thecæ valvate	Jungermanniaceæ.
Thecæ valveless	Marchantiaceæ.
Surface without stomates.	
Aquatics	Algaceæ.
Terrestrial or aerial.	
With a superficial thallus	Lichenaceæ.
Without a superficial thallus	Fungaceæ.

Dichotomous Analysis of the Natural Orders comprehended in the British Flora; according to the method of Lamarck.

1	Plants with distinct and visible flowers	2
	Plants without flowers	126
2	Leaves netted, wood in concentric layers	3
	Leaves straight-veined. Wood not in concentric layers	109
3	Flowers complete	4
	Flowers incomplete	53
4	Corolla polypetalous	5
	Corolla monopetalous	82
5	Stamens more than twenty	6
	Stamens fewer than twenty	17
6	Ovary inferior	7
	Ovary superior	8
7	Leaves with stipules	Pomeæ.
	Leaves without stipules	Nymphæaceæ.
8	Leaves with stipules	9
	Leaves without stipules	12
9	Carpels more or less distinct	Rosaceæ.
	Carpels consolidated	10
10	Calyx imbricated	Cistaceæ.
	Calyx valvate	11
11	Stamens monadelphous	Malvaceæ.
	Stamens distinct	Tiliaceæ.
12	Carpels distinct, more or less	13
	Carpels consolidated	15
13	Stamens perigynous	Rosaceæ.
	Stamens hypogynous	14
14	Calyx in a perfect whorl	Ranunculaceæ.
	Calyx in a broken whorl	Hypericaceæ.
15	Placentas parietal	Papaveraceæ.
	Placentas not parietal	16
16	Placentas spread over the dissepiments	Nymphæaceæ.
	Placentas in the axis	Cistaceæ.
17	Ovary inferior	18
	Ovary superior	23
18	Placentas parietal	19
	Placentas in the axis	20
19	Flowers unisexual	Cucurbitaceæ.
	Flowers hermaphrodite	Grossulaceæ.

20	Flowers in umbels	Apiaceæ.
	Flowers not in umbels	21
21	Fruit few-seeded	Cornaceæ.
	Fruit many-seeded	22
22	Fruit two-celled	Saxifragaceæ.
	Fruit four-celled	Onagraceæ.
23	Leaves stipulate	24
	Leaves exstipulate	34
24	Carpels distinct	25
	Carpels combined	26
25	Fruit leguminous	Fabaceæ.
	Fruit drupaceous or capsular	Rosaceæ.
26	Placentas parietal	27
	Placentas in the axis	28
27	Embryo minute. Leaves circinate	Droseraceæ.
	Embryo nearly as long as seed. Leaves straight	Violaceæ.
28	Styles distinct to the base	29
	Styles combined	31
29	Calyx broken whorled	Elatinaceæ.
	Calyx in a perfect whorl	30
30	Petals minute	Illecebraceæ.
	Petals conspicuous	Saxifragaceæ.
31	Gynobasic	32
	Not gynobasic	33
32	Fruit beaked	Geraniaceæ.
	Fruit not beaked	Oxalidaceæ.
33	Calyx valvate	Rhamnaceæ.
	Calyx imbricated	Portulacaceæ.
34	Carpels distinct	35
	Carpels combined	37
35	Carpels each with an hypogynous scale	Crassulaceæ.
	Carpels without an hypogynous scale	36
36	Anthers with recurved valves	Berberaceæ.
	Anthers with longitudinal valves	Ranunculaceæ.
37	Stamens tetradynamous	Brassicaceæ.
	Stamens not tetradynamous	38
38	Placentæ parietal	39
	Placentæ in the axis	41
39	Calyx tubular	Frankeniaceæ.
	Calyx polysepalous	40
40	Albumen large	Papaveraceæ.
	Albumen none	Resedaceæ.
41	Styles distinct to the base	42
	Styles more or less combined	46
42	Calyx in a broken whorl	43
	Calyx in a perfect whorl	44
43	Stamens polyadelphous	Hypericaceæ.
	Stamens monadelphous, or free	Linaceæ.

44	Carpels divaricating at the apex	Saxifragaceæ.
	Carpels not divaricating	45
45	Calyx tubular	Silenaceæ.
	Calyx many-leaved	Alsinaceæ.
46	Calyx in a broken whorl	47
	Calyx in a perfect whorl	
47	Calyx regular	Aceraceæ
	Calyx papilionaceous	Polygalaceæ.
48	Anthers opening by pores	Ericaceæ.
	Anthers opening by slits	49
49	Flowers unisexual	Empetraceæ.
	Flowers hermaphrodite	50
50	Calyx tubular	Lythraceæ.
	Calyx many-leaved	51
51	Fruit one-celled	Tamaricaceæ.
	Fruit many-celled	52
52	Stamens hypogynous	Monotropaceæ.
	Stamens perigynous	Celastraceæ.
53	Neither calyx nor corolla	54
	A calyx present	58
54	Fruit in cones	54*a*
	Fruit not in cones	54*b*
54*a*	Sexes distinct	Pinaceæ.
	Sexes imperfect (doubtful)	Equisetaceæ.
54*b*	Seeds naked, in a pulpy cup	Taxaceæ.
	Seeds in a capsule	54*c*
54*c*	Seeds tufted with hairs	Salicaceæ.
	Seeds not tufted with hairs	55
55	Fruit tricoccous	Euphorbiaceæ.
	Fruit indehiscent	56
56	Floating herbs	Callitrichaceæ.
	Woody plants	57
57	Fruit berried	Myricaceæ.
	Fruit a key (samara)	Oleaceæ.
58	Ovary inferior	59
	Ovary superior	65
59	Flowers unisexual	60
	Flowers hermaphrodite	61
60	Fruit cupuliferous	Corylaceæ.
	Fruit a fleshy pepo	Cucurbitaceæ.
61	Anthers many-celled	Loranthaceæ.
	Anthers two-celled	62
62	Ovary one-celled	63
	Ovary many-celled	Halorageæ.
63	Embryo curved	Chenopodiaceæ.
	Embryo straight	64
64	Albumen none	Halorageæ.
	Albumen fleshy	Santalaceæ.
65	Leaves stipulate	66
	Leaves exstipulate	72

66	Flowers hermaphrodite	67
	Flowers unisexual	70
67	Carpels consolidated	Ulmaceæ.
	Carpels solitary or separate	68
68	Calyx membranous	Illecebraceæ.
	Calyx firm and herbaceous	69
69	Styles single	Sanguisorbeæ.
	Styles triple	Polygonaceæ.
70	Carpels solitary	Urticaceæ.
	Carpels more than one	71
71	Flowers amentaceous	Betulaceæ.
	Flowers scattered	Euphorbiaceæ.
72	Flowers unisexual	Euphorbiaceæ.
	Flowers hermaphrodite	73
73	Carpels consolidated	74
	Carpels solitary or separate	77
74	Carpels two, divaricating	Saxifragaceæ.
	Carpels not divaricating	75
75	Stamens hypogynous	Alsinaceæ.
	Stamens perigynous	76
76	Fruit one-celled	Primulaceæ.
	Fruit many-celled	Lythraceæ.
77	Carpels several	Ranunculaceæ.
	Carpels solitary	78
78	Calyx herbaceous	79
	Calyx with a hardened tube	Scleranthaceæ.
79	Stipules ochreate	Polygonaceæ.
	Stipules none	80
80	Ovule pendulous	Thymelaceæ.
	Ovule erect	81
81	Leaves lepidote	Elæagnaceæ.
	Leaves naked	Chenopodiaceæ.
82	Ovary superior	83
	Ovary inferior	102
83	Flowers regular	84
	Flowers irregular	98
84	Ovary four-lobed	Boraginaceæ.
	Ovary undivided	85
85	Carpels more than four	86
	Carpels three or fewer	91
86	Anthers opening by pores	87
	Anthers opening by slits	88
87	Herbaceous plants	Pyrolaceæ.
	Woody plants	Ericaceæ.
88	A free central placenta	Primulaceæ.
	Fruit two-celled or more	89
89	Seeds indefinite	Crassulaceæ.
	Seeds definite in number	90
90	Ovules erect	Convolvulaceæ.
	Ovules pendulous	Aquifoliaceæ.

91	Flowers diandrous	Oleaceæ.
	Flowers not diandrous	92
92	Fruit one-celled	93
	Fruit more than one-celled	94.
93	Style single	Plantaginaceæ.
	Styles five	Plumbaginaceæ.
94	Calyx in a broken whorl	5
	Calyx in a perfect whorl	96
95	Corolla imbricated	Cuscutaceæ.
	Corolla plaited	Convolvulaceæ.
96	Corolla persistent	Gentianaceæ.
	Corolla deciduous	97
97	Leaves opposite	Apocynaceæ.
	Leaves subalternate	Solanaceæ.
98	Ovary four-lobed	Lamiaceæ.
	Ovary undivided	99
99	Capsule with a free central placenta	Lentibulaceæ.
	Placentas axile or parietal	100
100	Brown leafless parasites	Orobanchaceæ
	Leafy plants	101
101	Fruit indehiscent	Verbenaceæ.
	Fruit dehiscent	Scrophulariaceæ.
102	But one perfect carpel	103
	More than one perfect carpel	105
103	Anthers syngenesious	Asterales.
	Anthers free	104
104	Seeds albuminous	Dipsaceæ.
	Seeds exalbuminous	Valerianaceæ.
105	Anthers syngenesious	Lobeliaceæ.
	Anthers free	106
106	Anthers opening by pores	Vacciniaceæ.
	Anthers opening by slits	107
107	Seeds indefinite	Campanulaceæ.
	Seeds definite	108
108	Leaves whorled	Galiaceæ.
	Leaves opposite	Caprifoliaceæ.
109	Flowers complete	110
	Flowers incomplete	118
110	Ovary inferior	111
	Ovary superior	114
111	Flowers gynandrous	Orchidaceæ.
	Flowers not gynandrous	112
112	Anthers turned outwards	Iridaceæ.
	Anthers turned inwards	113
113	Stamens 6	Amaryllidaceæ.
	Stamens more than 6	Hydrocharaceæ.
114	Sepals calycine or glumaceous	115
	Sepals corolline	116

115	Carpels consolidated	Juncaceæ.
	Carpels separate	Alismaceæ.
116	Carpels consolidated	Liliaceæ.
	Carpels separate	117
117	Anthers turned outwards	Melanthaceæ.
	Anthers turned inwards	Butomaceæ.
118	Flowers glumaceous	119
	Sepals 0, or verticillate scales	121
119	Embryo external to the albumen	Graminaceæ.
	Embryo enclosed in the albumen	120
120	Seed erect	Cyperaceæ.
	Seed pendulous	Restiaceæ.
121	Leaves equitant	122
	Leaves not equitant	123
122	Anthers on long clavate filaments	Typhaceæ.
	Anthers sessile	Acoraceæ.
123	Flowers in a spathe	Araceæ.
	Flowers naked	124
124	Terrestrial plants	Juncaginaceæ
	Floating plants	125
125	Ovules pendulous	Naiadaceæ.
	Ovules erect	Pistiaceæ.
126	With a distinct stem	127
	Without a distinct stem	132
127	Leafless	Characeæ.
	Leafy	128
128	Thecæ seated on leaves	Filicales.
	Thecæ axillary	129
129	Thecæ valveless	Bryaceæ.
	Thecæ valvate	130
130	Thecæ with an operculum	Andræaceæ.
	Thecæ without an operculum	131
131	Thecæ four-valved	Jungermanniaceæ.
	Thecæ two-valved	Lycopodiaceæ.
132	Skin with stomates	133
	Skin without stomates	134
133	Thecæ valvate	Jungermanniaceæ.
	Thecæ valveless	Marchantiaceæ.
134	Aquatics	Algaceæ.
	Terrestrial or aerial	135
135	Thallus if any membranous and cellular	Lichenaceæ.
	Thallus if any filamentous	Fungaceæ.

Part IV.—Descriptive Botany.

Chapter I.

Of the importance of Descriptions.

Next to an accurate knowledge of the nature of plants, of the uses of their different parts, and of the manner of classifying them, is to be ranked the power of placing clearly and distinctly before the eye, a description that will enable a person previously unacquainted with a plant, not only to recognize it when he meets with it, but without seeing it to judge correctly of its exact nature, qualities, and affinities. No one is ever likely to have the leisure to examine personally all the plants that the world contains, but all must trust for the knowledge of a very considerable part of them to the descriptions given by others. If one could examine all known plants for one's self, the human mind would be incapable of retaining any distinct recollection of them, but would necessarily trust to descriptions made at the time of examination. If the number of plants to be studied is comparatively limited, still the minuteness of many of their parts is such as often to render dissection and microscopical investigation indispensable: these operations are tedious and difficult, and it would be exceedingly inconvenient, if it were necessary to go into a new investigation of the structure of a given plant every time that a new question arose as to the composition of its minuter parts: one good and careful description obviates the necessity of this, for it can always be referred to and consulted. Hence the great importance of Botanical descriptions, not only to the public but to Botanists themselves, for their private use. Nothing can in fact supply their place: dried specimens carefully arranged in an herbarium are the best substitute: but they are rather to be looked upon as evidence in aid of descriptions than as a means of supplying their place; and next to these come drawings. The latter, when well executed, are undoubtedly most valuable, and to a certain extent supply the place of descriptions; but it requires a much longer time to make a drawing than a description; very few persons know how to draw *correctly*, and still fewer are able to represent with the pencil with sufficient fidelity, what a description expresses in a few words.

Technical descriptions are, for these reasons, of the most indispensable necessity, and may be considered the very foundation of the systematic knowledge of all Botanists.

Chapter II.

Of popular Descriptions.

But it is to be remarked that however valuable descriptions of plants may be found when they are drawn up correctly and according to the exact rules of science, yet nothing is more perfectly useless than those which are prepared by persons ignorant of Botany; they are like the drawings of plants made by mere artists, more calculated to mislead than to instruct. For this reason, what are often called popular descriptions of plants, are mere misrepresentations, and either carry a false idea of that which they describe, or no idea at all. They may be well enough suited to amuse the ear, but they convey no distinct impression to the mind, even if they are tolerably correct as far as they go; for the purposes of poetry, and of sketching views of nature, they may be well enough suited; but they are like the blotches of red and green, and yellow, *put in* to a picture by a painter: the moment they are critically examined, they cease to produce the effect they are intended for.

Descriptions to be of any real use, must be drawn up with great care; every part of a plant must be either spoken of specifically, or so referred to as to be clearly indicated; the terms that are used must be employed precisely, and in the sense of Botanists; and there must be no misapplication of terms, no mistaking one part for another. To be able to write a description, a person must already be a very good Botanist; not a mere fetch-and-carrier of semibarbarous names, not a mere inventor of new species, not a compiler of the systematic writings of other persons; but thoroughly acquainted with the anatomical and external structure of the whole vegetable world, exactly informed upon the laws of organization,

aware of the relation that one part necessarily bears to another, ready to remark all deviations from normal conformation, and, to a certain extent, in possession of the general nature of systematical arrangements; in short, he must not only know how to observe, or how to describe, but how to estimate the value of what he observes, and to correct by the constant application of the general rules and principles of Botanical science the false observations to which we all are liable. Unless a man feels that he is capable of doing all this, he should not attempt to describe a plant Botanically; if it is necessary that he should make descriptions, the previous remarks will inform him of his deficiencies, and he ought to qualify himself for the task. The great cause of the slow advance of Botany is in no inconsiderable degree to be ascribed to the incompleteness or inaccuracy of Botanical descriptions.

As the only satisfactory mode of illustrating the observations now made, will be to quote examples, we may take, as a striking instance of useless descriptions the following popular account of the tree that yields the aromatic bark called Cassia, in the island of Sumatra; see Marsden's History of that island, 3rd edition, p. 156.

"(1.) The leaves are about four inches long, narrower than the bay (to which tribe it belongs), and more pointed; deep green; smooth surface, and plain edge. (2.) The principal fibres take their rise from the peduncle. (3.) The young leaves are mostly of reddish hue. (4.) The blossoms grow six in number, upon slender footstalks, close to the bottom of the leaf. (5.) They are monopetalous, small, white, stellated in six points. (6.) The stamina are six, with one style, growing from the germen, which stands up in three brownish segments, resembling a cup. The trees grow from fifty to sixty feet high, with large, spreading, horizontal branches, almost as low as the earth."

In this case, which we take in preference, as having been published by a clever man, and one who was something of a naturalist, there is not a particle of information that a Botanist could make use of, as we proceed to shew sentence by sentence.

(1.) Nothing is said of the form of the leaves; we are merely told that they are narrower than those of the bay; but they might be narrower and yet very differently formed: not a word is mentioned concerning the arrangement of the veins, nor is the position of the leaves upon the stem described. It is said indeed that the plant belongs to the same tribe as the bay (namely Lauraceæ), and this would no doubt imply that the leaves are alternate; but then a little further on (sentence 5), the affinity of the plant to the bay is contradicted, by the flowers being called monopetalous.

(2.) It is impossible to understand the meaning of this sentence. What fibres are meant? Strong lateral veins in the leaf resembling the midrib? But this can hardly be: first, because the sentence, by the punctuation, is cut off from what relates to the leaf; and, secondly, because the fibres spoken of are referred to the peduncle, that is to say, to the flower stalk. A good Botanist might guess at the meaning of the passage, but it could only be a guess, and after all might be wrong.

(3.) This is unimportant.

(4.) Vague and unsatisfactory. We are told that the flowers grow *close* to the bottom of the leaf; not at the bottom, but close to it; Do they spring then from the lower part of the petiole, or from the stem above the axilla? Are they single, or do they grow upon the ramifications of a panicle, cyme, corymb, or raceme?

(5.) If the plant belongs, as stated, to the bay tribe, the flowers cannot be monopetalous. If they really are monopetalous, where is the calyx, and what is its nature?

(6.) The style is said to grow from the germen. From what other part could it grow? The germen is said to stand up in three brownish segments, resembling a cup: if so, the plant can have nothing to do with the bay tribe. The position of the stamens, the nature of their dehiscence, and their origin, are all omitted.

Such are the observations that suggest themselves to the Botanist, in merely reading over this description; and they are amply sufficient to show how useless it is. But collateral evidence tells us that what Marsden intended to describe, was the plant called *Cinnamomum nitidum;* and that fact being ascertained, the following has to be added to the criticism upon the description. The calyx is called corolla (5); the stamens are 9, not 6 (6); the

name of germen is applied (6) to three steril stamens, and the germen itself, that is to say the ovary, is overlooked!

Chapter III.

Of careless Descriptions.

If such descriptions as that just mentioned, are scientifically useless, how much worse must those be which proceed from professed Botanists, in whose supposed knowledge and technical skill, one would think that confidence may be reposed! In the works of many of the disciples of Linnæus, the descriptions of plants are so meagre, inaccurate, and unsatisfactory, that to this day they would remain mere Botanical enigmas, if the meaning of the authors had not been determined by other evidence than what they themselves afford. Pre-eminent among such Botanists, stands Thumberg, from whose Flora Japonica we extract the following description of the fructification of a new genus he calls Nigrina:

"Calyx none, except a one-leaved bract. Corolla of four petals. Filaments four, very short; anthers globose, white. Germen superior; style single; stigma .... Fruit unknown; perhaps a capsule."

This is all the information given concerning the fructification of a plant which the author considered undescribed, and of which he saw fresh specimens. Supposing the description to be accurate as far as it goes, it excludes every one of the points which it is most essential to be acquainted with; the origin of the stamens, the dehiscence of the anthers, and their æstivation; the relation of the stamens to the petals, the internal structure of the ovary, the number and adhesion of the ovules, all essential points for consideration,—and the more indispensable because of the absence of the fruit of the plant,—are passed by in silence. But as if to compensate for the omission of what it was necessary to state, irrelevant matter is introduced into this description, brief as it is. The bract is called one-leaved: if the plant had *a* bract, it could be no more than one-leaved; if the reverse, then it would no longer be *a* bract. The anthers are said to be white, but their colour is of no importance. But what is most extraordinary, the description is altogether false. The flowers have neither calyx nor corolla; the filaments are three, not four, and the anthers are not globose, but irregular, ovate, fleshy bodies.

Chapter IV.

Of technical Descriptions.

The observations now made upon faulty descriptions, will have given the reader some idea of the manner in which plants ought *not* to be described. We now proceed to explain how they should be described for practical purposes. In the first place, every point of structure of any importance should be introduced; what is important or not can never be reduced to any fixed standard, but varies according to the nature of the plant in question, and has in all cases to be determined by the Botanist himself. All technical terms should be used in their exact sense, if used at all; and nothing should be overlooked that can in any way tend to elucidate structure. It is not however necessary to be excessively minute, unless in the case of plants that are not only quite unknown, but whose natural affinity is also uncertain. When such a plant is to be described, every part of the organization, microscopic or obvious, should be included, and nothing should be taken for granted as unimportant. But as cases of this kind are hardly likely to come within the experience of those who use such a treatise as this, it is unnecessary to go into such details. It will be sufficient to confine attention to common instances.

Another essential circumstance to attend to is, always to describe the parts of a plant in the following order. 1. Root. 2. Stem. 3. Leaves, and stipules, if any. 4. Inflorescence. 5. Bracts, if any. 6. Calyx. 7. Corolla. 8. Stamens; distinguishing filaments and anthers. 9. Ovary and ovules; style; stigma. 10. Fruit. 11. Seed. By paying attention to this, one always knows in what part of a description to look for information concerning a particular organ; whereas if the different parts were spoken of in a confused manner, one would never be certain whether an organ was described or not, without reading through the whole description.

Keeping in view such rules as these, a Botanist may make his descriptions in two ways, either in a diffuse and

readable, or in a terse and technical manner. To the former there is no objection, where space is unimportant, or where the description is to be read by persons who would be repelled by the stiffness and formality of technical phraseology; the latter would, under such circumstances, be misplaced; but it is nevertheless that which must be generally employed, as may be proved in the following manner:

Let the following be the Botanical description of a Wild Heart'sease (Viola tricolor), drawn up in a popular readable way.

The root of this plant consists of a great number of unequal irregular fibres. The stems first fall prostrate, and then rise up, and are perfectly smooth all over the surface; their form is square, their interior is hollow, and at every place where the leaves are set on, they are a little tumid. The leaves grow upon opposite sides of the stem at tolerably equal distances, one above the other; they have a form between ovate and oblong, have a distinct leaf stalk, and are coarsely cut at their edges in a serrated manner; they are quite destitute of hairiness, and are longer than the stipules which grow at their base. The stipules in colour and texture resemble the leaves; they are cut almost to the middle into a number of narrow lobes, of which the terminal one is much the largest; at the base they are prolonged more on one side than another, in a hastate manner. The beautiful little flowers grow singly from the stem, at the places where it joins the leaves, and they have a nodding position on their peduncle; the latter has a smooth surface, is distinctly angular, curves inwards at the upper end, and has a twist somewhere near its middle. At the upper end of the peduncle grow two small bractlets, resembling fine scales, prolonged at the base into something of a hastate figure. The calyx of this plant consists of five distinct sepals, having the same colour and texture as the leaves; they are of a narrow ovate form, sharp-pointed, quite free from hairs, not in any way lobed or divided, and extended below the point of origin into a flat rounded appendage, which is divided by small toothings at the edge: of the sepals, those which stand next the front of the flower are much the largest. The corolla consists of five petals, which are of unequal size, oblong, with a little stalk at the base, and rounded at the upper end; the two uppermost are larger than the rest, of one uniform purple colour, while the three lower are yellow, with purple lines at the base, and furnished with a little tuft of hair at the bottom of the streaks; the intermediate one of these petals is furnished with a short straight spur at the base. The stamens are five in number, inserted into the line between the base of the ovary and the sepals, not so long as the claws of the petals, and of unequal size; the anthers have no filaments, are of a membranous texture, are fringed with white hairs at the edge, and are extended into a broad brown membranous appendage at the point; those two stamens which stand in front of the flower are longer than the others, and protrude from their base on one side a green slender thread-shaped process, which is introduced into the spur of the front petal of the corolla. The ovary has no adhesion to the sepals, is of a spheroidal form, and contains one single cell; on its inside, the ovules, which are very numerous, grow to thrice broad lines running from the apex to the base of the cavity at equal distances; the ovary is terminated by a style, smooth, thickest at the upper end, bent like the letter S, and bearing at the point a round hollow stigma, through one side of which there is an opening into the interior. The ovary, when ripe, changes to a seed vessel of a dry, cartilaginous consistence, containing one cell, and dividing into three equal spreading ovate-lanceolate valves between the broad lines on which the seeds are inserted, so that when the valves are spread open, the seeds are seen sticking to the middle. The seeds are small, shining, oblong bodies, rather narrow at the lower end, and of a pale brown colour; the point of attachment to the placenta is thickened in a fungus-like manner; from this part there rises a fine elevated line, which terminates in a depressed discoloured round spot, stationed at the top of the seed. In the interior is found an embryo of a deep green colour, quite straight, and having a taper radicle, with thin flattened cotyledons a little rounded at the back. Surrounding the embryo is found a quantity of fleshy brittle albumen, in the very axis of which the embryo is placed.

There is nothing in this to which a Botanist could object, except that certain points are omitted, such as the

æstivation of the calyx and corolla, the dehiscence of the anthers, the form of the pollen, and some other matters of a similar kind. But it is also obvious that if all the 100,000 plants supposed to be known were to be described in this manner, and at this length, the mere descriptions alone would occupy 200 volumes like the present, of 500 pages each. It is therefore indispensable that such descriptions should be shortened: and it will be seen by the following specimen, that the *very same* facts, before occupying 106 lines, may be stated in 43 lines, by the mere omission of verbs, articles, superfluous words, and rendering it rather more technical.

Root fibrous. Stems decumbent, smooth, square, fistular, slightly tumid at the nodes. Leaves alternate, ovate-oblong, petiolate, coarsely serrated, smooth, longer than the stipules; stipules leafy, pinnatifid, half-hastate; terminal lobe much the largest. Flowers solitary, axillary, nodding; peduncles smooth, angular, twisted, incurved at apex. Bractlets two, minute, membranous, sub-hastate near the apex of the peduncle. Sepals five, herbaceous, linear-ovate, acute, smooth, entire at the base, prolonged into a concave, rounded, tooth-letted appendage; the anterior much the largest. Petals five, unequal, oblong, unguiculate, rounded at the apex; the two upper largest, whole coloured, purple; the three lowest yellow with purple streaks, and bearded at base; that in the middle having a short straight spur at the base. Stamens five, hypogynous, shorter than the ungues, alternate with the petals, unequal; anthers sessile, membranous, ciliated, with a broad brown membrane at apex; the two anterior the largest, spurred; their spurs green, subulate, lying in the spur of the corolla. Ovary superior, round, one-celled, with three parietal polyspermous placentæ; style smooth, sigmoid, clavate, as long as the ovary; stigma capitate, hollow, with an oblique foramen on one side. Capsule one-celled, three-valved, with a loculicidal dehiscence; valves ovate-lanceolate, spreading, seminiferous in the middle. Seeds shining, roundish, smooth, pale brown; hilum fungous; raphe elevated; chalaza depressed on the apex. Embryo straight, green, in the axis of fleshy albumen; radicle terete; cotyledons plano-convex.

This last description does not in fact then occupy more than 3-8ths as much space as the first, and yet it comprehends every one of the facts included in the first.

But even the admission of descriptions cut down like the last, would render books infinitely too bulky; and therefore by the introduction of generic and specific characters, they are still further shortened.

Chapter V.

Of Generic and Specific Characters.

It has already been explained that a genus is a collection of species agreeing with each other in certain common features; see p. 139. In reducing descriptions like the last, the whole of those common features are separated as a generic character, and given once only at the beginning of the descriptions of the species, and from the descriptions of the species all such common features are omitted. Thus to pursue the illustration with this same Viola tricolor, the following is abstracted to form the generic character of

Viola.

Leaves alternate. Flowers solitary, axillary. Sepals five, herbaceous, prolonged at the base into an appendage, the anterior much the largest. Petals five, unequal, unguiculate; the two upper largest; the lowest one spurred at the base. Stamens five, hypogynous, shorter than the ungues, alternate with the petals, unequal; anthers sessile, with a broad membrane at the apex; the two anterior the largest, spurred; their spurs lying in the spur of the corolla. Ovary superior, one-celled, with three parietal polyspermous placentæ; style sigmoid, clavate; stigma capitate, hollow, with an oblique foramen on one side. Capsule one-celled, three-valved, with a loculicidal dehiscence; valves seminiferous in the middle. Seeds roundish; hilum fungous; raphe elevated; chalaza depressed on the apex. Embryo straight, green, in the axis of fleshy albumen; radicle terete; cotyledons plano-convex.

All the foregoing being abstracted for a generic character, then the following would be all that would be necessary as a description of

Viola tricolor.

Root fibrous. Stems decumbent,

smooth, square, fistular, slightly tumid at the nodes. Leaves ovate, oblong, petiolate, coarsely serrated, smooth, longer than the stipules; stipules leafy, pinnatifid, half-hastate; terminal lobe much the largest. Flowers nodding, peduncles smooth, angular, twisted, incurved at apex. Bractlets 2, minute, membranous, sub-hastate, near the apex of the peduncle. Sepals linear, ovate, acute, smooth, entire; appendage concave, rounded, toot-hletted. Petals oblong, rounded at the apex, the two upper whole coloured purple, the three lowest yellow, with purple streaks, and bearded at the base. Anthers ciliated; the spurs green, and subulate. Ovary round; style smooth. Seeds shining, smooth, pale brown.

This last process of reduction has brought the description of Viola tricolor from 106 to 20 lines in length, without the omission, in fact, of a single character. Further than this it cannot be reduced, if to remain a description.

But as the number of species known to Botanists is exceedingly great, even such descriptions as the last are found too extensive to be employed in all cases; the older Botanists, therefore, contrived what they called *differential or factitious characters*, to stand in lieu of descriptions. In contrasting a number of species of the same genus, it is obvious that if no other points are to be adverted to than such as will distinguish them from each other, the words required to distinguish such species may be extremely few, and that a description may thus be conveniently exchanged for a mere differential expression; it cannot, however, be altered into one; for it no longer remains a description, but a certain form is substituted for it. In order to prevent these specific characters ever extending into descriptions, Linnæus proposed that they should in no case exceed the extent of twelve Latin words; and he rarely, if ever, deviated from that standard.

Take, for instance, his specific characters in the genus Drosera:

1. D. *rotundifolia*. Scapes from the root. Leaves orbicular.
2. D. *longifolia*. Scapes from the root. Leaves oblong.
3. D. *capensis*. Scapes from the root. Leaves lanceolate.
4. D. *lusitanica*. Scapes from the root. Leaves subulate, convex beneath.
5. D. *cistiflora*. Stem simple, leafy. Leaves lanceolate.
6. D. *indica*. Stem branched, leafy. Leaves linear.

By these few words some of the principal differences between the six Droseras known to Linnæus are plainly expressed; but it is obvious that they are not to be confounded with descriptions.

The plan of specific characters devised by Linnæus has been adopted down to the present day; but it is much to be doubted whether they have not been disadvantageous to Botany, rather than the contrary. If, indeed, a systematic writer could say that he is distinctly acquainted with every species in the world of a given genus, then such differential characters would doubtless be invaluable, as they would help another person to arrive rapidly at a definite conclusion concerning any plant he might have for examination. But this is not the case; and therefore the differential characters only lead to error and misapprehension. For instance, Linnæus assigns to Drosera rotundifolia the character of "scapes from the root," and "leaves orbicular;" and this would be a useful character of the species, if those characters existed nowhere else. But we now know that D. uniflora, pygmæa, and rotundifolia all agree in this character; and consequently it is impossible to tell which of the three Linnæus meant, if we judge only from his specific character. And if we alter the phraseology so as to distinguish these three species from each other today, to-morrow may bring us acquainted with other species, which will in like manner render the newly altered differential character nugatory.

For these reasons the specific characters of Linnæus have given rise to endless confusion and doubt, and will continue to do so as long as they are employed, unless they are accompanied by longer descriptions. The present practice seems to be to employ short descriptions, or essential characters, in lieu of differential characters; and this upon the whole may be considered better.

Chapter VI.

Of Essential and Natural Characters.

We shall conclude this part of our subject with some observations upon the distinction between descriptions of the essential and natural characters of plants.

An essential character is a descrip-

tion of all those points which the observer supposes to be most important, not only in distinguishing it from all other known plants, but from such as his information concerning allied species induces him to anticipate the discovery of. If applied to a species, it omits all notice of varieties of an accidental and fugitive nature, and is constructed only with reference to general, and not particular circumstances. If applied to a natural order, it neglects variations from the typical structure, and confines itself to the normal organization, or what the describer considers to be so, stating that in brief terms. In short, it is, when applied to genera and species, what modern Botanists call a generic or specific character, and is the usual description given of a natural order in general works. Linnæus rightly considered it to be of great value, but extremely difficult to draw up. It is sometimes called a Diagnosis.

A Natural character, on the other hand, is a complete description of the organization of a given species, genus, or order, including an account of every part, and comprehending every deviation from normal structure, whether habitual or accidental. It can only be drawn up at great length, and from its length is only suited to monographs. It is, however, if well drawn up, of the greatest consequence. Linnæus, who however did not understand it in the modern sense, says, "basis est omnium systematum, generum infallibilis custos, omnique systemati possibili et uno applicabilis." And again, "If the Natural characters of all genera had been detected, the knowledge of plants would be very easy; and it is only to their own loss that many Botanists undervalue them. But they ought to know that no one can be a sound Botanist without an acquaintance with natural characters; for a Botanist must, in the absence of Natural characters, be in continual uncertainty as often as new genera are detected. He who fancies he is acquainted with Botany by the use of mere Essential characters, neglecting the natural ones, only deceives others as well as himself; for all Essential characters must become fallacious as fast as new genera are discovered. Natural characters are the very foundation of genera, which it is impossible to understand without them; and therefore they are, and always will be, the foundation of all knowledge of plants."

Although Linnæus did not, as has already been observed, apply the word Natural character in its modern sense, yet these declarations of that distinguished man are quite applicable to such descriptions as are here alluded to. The following descriptions of the important natural order Compositæ, or of what we have called the Group Asterales (p. 182), will illustrate the subject of this discussion, and conclude what it appears necessary to introduce in this place from the subject of Descriptions.

Asterales or Compositæ.

Essential Character.

Corolla monopetalous. Stamens syngenesious. Ovary inferior, one-celled; ovule erect. Seed without albumen.

That is to say, all plants agreeing with this description in all its parts, belong to Asterales.

Natural Character.

Vegetation. Herbs, usually perennial, or shrubs, or more rarely (principally in insular situations), trees, occurring all over the world, and forming about a tenth part of the whole vegetable kingdom. Leaves alternate or opposite, extremely variable in form, lobing, or aspect, always simple, never compound. Stem (when simple) or branches terminated by a head or glomerule. Branches generally corymbose, those in the middle the earliest. Leaves stationed below the heads or glomerules usually different from the rest, and called floral or bracteal, changed into scales sometimes gradually, sometimes abruptly, and then much larger than the scales. Corollas now xanthic, now cyanic in the same head, either homochromous or one-coloured, or heterochromous or two-coloured; when two-coloured the ligulate always cyanic and the tubular xanthic; even when the xanthic tubular corollas become ligulate owing to any monstrosity, they also become cyanic! Proper juice variable, sometimes milky. Taste usually bitter, astringent, and aromatic.

Inflorescence.—Flowers collected into a *head* or *glomerule.* Heads consisting of several florets upon a receptacle or end of a branch, whether flat, or conical, or lengthened; the exterior or outer earliest; the interior by degrees later. Flowers either all hermaphrodite, and then the heads homogamous; or the

exterior neuter or female, the inner hermaphrodite, or male, and the heads then heterogamous ; or all in the same plant, either male or female, and then the heads either monœcious, that is, both male and female, or heterocephalous, that is, some male some female, or diœcious; that is, all males or females upon the same plant. Heads either with all the corollas tubular, and then called discoidal, or floscular; or with all the corollas ligulate, and then called ligulate, or formerly, semifloscular; or with the corollas of the margin or ray ligulate, of the centre or disk tubular, and then termed radiant; or all bilabiate, and then falsely discoidal; or ligulate at the margin, and bilabiate in the centre, and then falsely radiant or radiatiform. Discoidal, and falsely discoidal heads have sometimes marginal flowers like the others, but larger, and are then called coroneted (coronata). Involucrum consisting of many scales, in one or several rows, free, or (if in one row) united at the edges ; dry, scarious, coriaceous, fleshy, spiny, or leafy, often separated into the scale proper, and its appendage; the rows equal or more usually unequal, imbricated, or calyculate, or variously and somewhat irregularly lengthened. Glomerule consisting of one or few flowered heads, furnished with an involucre proper, densely and variously aggregated, surrounded by a general involucrum, seated on a general receptacle ; the flowers of the centre generally the earliest; the exterior later, or flowering in no determinate order. Receptacles of the head either foliaceous, that is, furnished with paleæ resembling the scales of the involucrum, situated at the outer side of each flower, articulated above their base, and in occasional monsters expanded into true leaves ; or semipaleaceous, namely, furnished with paleæ towards the outside only; or epaleaceous, or naked ; that is altogether destitute of paleæ. In some heads (or perhaps glomerules very closely packed together) the receptacle is called sometimes fimbrilliferous, when each flower is surrounded on all sides with a socket scaly at base, and divided at the edge into irregular plates or bristles ; sometimes alveolate when the sockets are shallow and not extended into bristles, but often tooth-letted ; or finally, areolate, when a pentagonal area, the rudiment of a socket, bounds the base of each flower. Possibly a receptacle more or less paleaceous designates flowers really spiked, and heads in the proper sense of the word; while the fimbrilliferous or alveolate receptacles indicate heads closely packed together, and, properly speaking, umbellate, the sockets representing the rudiments of an involucrum. To speak more plainly, the heads are arranged upon the plan either of a contracted spike or a contracted umbel.

Fructification.—Calyx monocepalous, adhering to the ovary; the tube sometimes equal to the ovary, sometimes longer ; its limb or pappus either altogether deficient, or reduced to a narrow rim, very rarely leafy, or more frequently scarious, entire, toothed, lobed, or breaking up into paleaceous scales, or hair-like bristles; simple, branched, tooth-letted, or feathery; one, two, or many rowed. Corolla monopetalous, inserted into the top of the tube of the calyx, neuramphipetalous, that is, having the petals furnished with two nervures next the margin; whence usually five nervures in the tube (ten united in pairs) stretching from the base to the sinus of the lobes, and ten in the lobes, that is, marginal to each lobe; with the addition here and there of accessory nervures in the middle of the petals, and these in a very few instances being the only ones that are distinguishable. Tube variable in length, extending from the base to the insertion of the filaments. Throat usually distended from the insertion of the filaments, as far as the separation of the lobes ; lobes generally five, rarely four, or three, or two ; valvate in æstivation, sometimes all equal, sometimes almost equal, or irregular, unequal, or palmate; sometimes bilabiate (or three for the outer lip, two for the inner, or four for the outer, one for the inner); sometimes, in consequence of a fissure carried down the inside, expanded into a five-toothed flat ligula. Stamens five, rarely four, in the female or neuter flowers deficient or rudimentary; filaments alternate, with the lobes of the corolla, and therefore corresponding with the nervures of the tube, adnate to the tube of the corolla, free upwards; either wholly distinct from each other, or combined into a tube, and therefore monadelphous, towards the apex articulated, the upper antheriferous joint standing in place of a connective. Anthers erect, in one row, combined into a tube perforated by the style (syngenesious or synan-

thereous), linear, two-celled, opening inwards by a longitudinal cleft, four-valved, the valve turning outwards, at the apex prolonged into an appendix or wing, varying in form and size in different species, and frequently of a different consistence from the part that bears the pollen ; at the base often extended into two tails of variable length and form. Pollen globose or elliptical, rough or smooth. Ovary monocarpellary, adhering to the calyx, one-seeded. Style taper, or more rarely tumid at the base (and then called bulbous), usually in the male flowers quite simple if present, in the females and hermaphrodites bifid at the end; its arms (or vulgarly stigmas) plane above, convex beneath ; either altogether distinct, or more or less united. Stigmatic glands (stigmas properly speaking) in two rows, situated upon the upper face of the arms of the style, in continuous marginal rows, roughish, more or less prominent or distinct. Collecting hairs of pollen rigid, on the upper part of the style in hermaphrodite flowers, or on its arms at the lower side or apex; in the female flowers neuter, or almost none. Fruit, or achenium, composed of the tube of the calyx, the pericarp and the seedskin, more or less completely combined, and enclosing the embryo. Achenium, therefore, one-celled, one-seeded, articulated with the receptacle, most commonly sessile, more rarely stipitate, having an open space (areola) at its base or side, either beakless or rostrate at the point, surmounted by the pappus already described, terminated by an epigynous disk, surrounding the central nectary, which is continuous with the ovary and style-shaped, or socket-like. Seed fixed by a very short cord to the lowest part of the fruit, erect, attached by the base at the side opposite the cord. Lining of the seedskin (albumen Lessing), thickish, tender, semi-transparent, traversed by a double cord. Embryo erect, straight, exorhizal, dicotyledonous; radicle short, straight ; plumule generally inconspicuous, cotyledons plane, usually rather convex at the back, very rarely curved, sometimes accidentally three in number.

It must be obvious to every one, upon reading the foregoing description, that it is so constructed as to comprehend every kind of structure that Composite plants ever present, and that consequently the working Botanist can tell at once, by glancing his eye over the paragraphs, what the structure and limits of variation are of any particular organ, without undertaking the labour of a long and tedious, or perhaps impossible examination for himself. At the end of seven years' constant study, Professor De Candolle, from whom the description is translated, is able to state what the real characters of these plants are, and by putting his knowledge into this technical form, he renders it available for any other Botanist upon ten minutes' study.

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ANIMAL PHYSIOLOGY.

The term Physiology, derived from two Greek words, one of which signifies *nature*, and the other *an account of*, appears to have been originally employed to designate a discourse concerning natural objects in general. For a long time past, however, this word has been restricted to a science which comprehends only a particular class of beings, distinguished by peculiar and very important characters. *Organization* confers on the bodies which possess it properties sufficiently distinctive to form the basis of a division of all the objects in nature into two great classes, namely, the inorganic and the organic.

In general, inorganic bodies possess no determinate structure. In some few, indeed, as in crystals, there is a definite and uniform arrangement of the component particles: but, even in these, as well as in inorganic bodies generally, these particles are merely in a state of aggregation, without mutual relation or dependence; the motions of their entire mass are regulated by certain physical laws, the operation of which is fixed and invariable; and the motions of the integrant parts, and all the results of such motions, are equally determinate, while they are ascertained, or ascertainable, by direct experiment. The science which treats of this immense class of bodies, commonly termed Natural Philosophy, receives, in its primary divisions, different names, according to the kind of properties which it is its object to investigate. Thus, the science, which has for its subject quantity in general, is termed Mathematics; figure, Geometry; motion, that is, motion of entire masses, Dynamics: while that which investigates the motion of the integrant particles of masses, and the results of such motion, is denominated Chemistry.

Organized beings possess certain properties in common with inorganic bodies; but to these others are superadded, by which they are distinguished, and which modify the first in a very wonderful manner, and to a very extraordinary extent. The sciences which treat of organized beings are two only: one has for its subject their structure, the other their functions: the first is termed Anatomy, the second, Physiology.

As far as can be determined by observation, organization has an inseparable relation to life, and life to organization. We see life only in organized bodies: we see organization only in living beings. That peculiar serios of phenomena which is exhibited by organization when in action, that is, by living beings, constitutes the subject of Physiology. Physiology, then, is the science which investigates the functions of living beings: it is the doctrine, the science of life.

Who has not put to himself the question, What is life? Who would not receive a clear and just solution of the inquiry with a feeling of interest far beyond that afforded by the successful result of ordinary scientific investigation? We know the mechanism by which life acts: we *feel* its result. We see that that mechanism is so delicate, so complicated, so fragile, so easily set wrong, while our own interest is so deep that it should go well, and permanently well, that the exquisiteness of adjustment, the skill of contrivance, the completeness with which the intended result is secured, all subjects of distinct and interesting investigation, only increase the earnestness of our wish, that we could see beyond the mechanism, and understand that which it is permitted us to know only by consciousness. In this inquiry, we cannot forget that we ourselves are the subjects of the investigation, and that all we have, and are, and hope, are involved in the mystery; and the more we pursue the inquiry, the deeper we feel that there are few subjects which the human mind can

study which have a greater tendency to excite its wonder, to fill it with admiration, to penetrate it with gratitude. We do not commonly consider *how much* is given us in life: the daily enjoyment of the boon, renders us insensible of the variety and plenitude of its richness: we become more sensible of it when we contemplate the number of tissues that have been formed; the number of properties that are attached to each; the number of organs that are constituted by their aggregation and arrangement; the number of functions that are exercised by those organs; and the number of adjustments by which all are combined and harmonized, and made effectual to the production of one grand result: it is then we perceive how many things must exist, how many relations must be established, how many actions must be performed, how many combinations of actions must be secured, before there can be sensation, and motion, and thought, and happiness.

Physiologists of the highest distinction have spoken of life without reserve or explanation, as a principle or a power; a real and distinct agent, upon which the various phenomena of life depend. But life, as far as we affix any *scientific* meaning to the word, is a peculiar mode of being, in which a certain series of phenomena are observed to take place; these phenomena are never found associated with any other conditions, but that one to the designation of which the term life is appropriated: hence we use this word, merely as the short expression by which this peculiar state of being, or the associated phenomena which constitute it, are denoted. What life is, independently of this series of phenomena, we are wholly ignorant, as we are of everything but appearances in relation to every object in nature.

When these signs of life are carefully considered, it will be found that they are reducible to five, or that there are five properties which are peculiar to living beings, and by which therefore they are distinguished. Of these, the first is the property they possess of resisting, within certain limits, the operation of the ordinary laws of matter. Physical agents exert over inorganic bodies a constant and irresistible influence. Air, moisture, heat, produce, in all such bodies, incessant changes, subverting the closest union between their integrant particles, and forming them into combinations entirely new. If a living being be brought under the influence of these agents, it is found capable of resisting such changes within a very considerable range, and it retains this power as long as it continues to be a living being. Thus the living body is not decomposed under degrees of temperature and moisture, which begin to resolve it into its primitive elements the moment it is dead. There is a certain temperature, different in different cases, at which the functions of the economy are performed in the best manner, and all living beings have the power of preserving that temperature, within a very considerable range, whatever may be the degree of heat or cold of the medium that surrounds them. The heat of a tree examined by Mr. Hunter was found to be always several degrees *above* that of the atmosphere when the atmospheric temperature was below 56° Fahrenheit; but it was always several degrees *below* it when the weather was warmer. The sap taken from the tree was found to freeze at 32°; while in the tree, it would not freeze below 47°. But animals exhibit the most surprising power of resisting the different degrees of heat or cold of the surrounding medium. The power of the superior animals, and especially of man, to resist high degrees of temperature, at first discovered by accident, and afterwards made the subject of direct experiment, is very extraordinary. In the year 1760, at Rochefoucault, Messieurs du Hamel and Tillet, having occasion to use a large public oven on the same day in which bread had been baked in it, wished to ascertain with precision its degree of temperature. This they endeavoured to accomplish by introducing a thermometer into the oven at the end of a shovel. On being withdrawn, the thermometer indicated a degree of heat considerably above that of boiling water; but M. Tillet, convinced that the thermometer had fallen several degrees on approaching the mouth of the oven, and appearing to be at a loss how to rectify this error, a girl, one of the attendants on the oven, offered to enter, and mark with a pencil the height at which the thermometer stood within the oven. The girl smiled at M. Tillet's appearing to hesitate at this strange proposition, and, entering the oven, marked with a pencil the thermometer as standing at 260° of Fahrenheit's scale. M. Tillet

began to express his anxiety for the welfare of his female assistant, and to press her return. This female salamander, however, assuring him that she felt no inconvenience from her situation, remained there ten minutes longer, when at length, the thermometer at that time standing at 288°, or 76° above that of boiling water, she came out of the oven, her complexion indeed considerably heightened, but her respiration by no means quick or laborious. The publication of this transaction exciting a great degree of attention, several philosophers repeated similar experiments, among which the most accurate and decisive were those performed by Drs. Fordyce and Blagden. The rooms in which these celebrated experimentalists conducted their researches were heated by flues in the floor. There was neither any chimney in them, nor any vent for the air, excepting through the crevice at the door. Having taken off his coat, waistcoat, and shirt, and being furnished with wooden shoes tied on with lint, Dr. Blagden went into one of the rooms as soon as the thermometer indicated a degree of heat above that of boiling water. The first impression of this heated air upon his body was exceedingly disagreeable; but in a few minutes all his uneasiness was removed by the breaking out of a sweat. At the end of twelve minutes he left the room very much fatigued, but no otherwise disordered. The thermometer had risen to 220°. In other experiments it was found that a heat even of 260° could be borne with tolerable ease. At these high temperatures every piece of metal about the body of the experimenters became intolerably hot; small quantities of water placed in metallic vessels quickly boiled. Though the air of this room, which at one period indicated a heat of 264°, could be breathed with impunity, yet, of course, the finger could not be put into the boiling water, which indicated only a heat of 212°; nor could it bear the touch of quicksilver heated only to 120°; nor scarcely that of spirit of wine at 130°. But in a physiological view, the most curious and important point to be noticed is, that while the body was thus exposed to a temperature of 264°, the heat of the body itself never rose above 101° or at most 102°. In one experiment, while the heat of the room was 202°, the heat of the body was only 99½°, its natural temperature in the state of health being 98°. But animals are capable of living in temperatures of extraordinary elevation even in the dense medium of water. Dr. Clarke states, that in one of the tepid springs of Bonarbashy, situated near the Mender, in which the thermometer rose to 62° Fahrenheit, fishes were seen sporting in the reservoir. In the thermal springs of Bahia, in Brazil, small fishes were seen swimming in a rivulet that raises the thermometer to 88°. Sonnerat states, that he found fishes existing in a hot spring at the Manillas at 158°. M. Humboldt and M. Bonpland, in travelling through the province of Quito in South America, perceived fishes thrown up alive, and apparently in good health, from the bottom of a volcano, along with water and heated vapour that raised the thermometer to 210°, being only 2° short of the boiling point. This power of resisting temperature belongs, in an almost equal degree, even to the vegetable world. M. Sonnerat found the *vitex agnus castus*, and two species of *aspalathus* on the banks of a thermal rivulet in the island of Lucon, the heat of which raised the thermometer to 174°, and so near the water that its roots swept into it. Around the borders of a volcano in the Isle of Tanna, where the thermometer stands at 210°, Mr. Forster found a variety of flowers flourishing in the highest state of perfection. Confervæ and other water-plants are by no means unfrequently traced in the boiling springs of Italy raising the thermometer to 212°, or the boiling point. The temperature at which these beings preserve their life and health, and maintain the heat of their bodies at nearly the same point as is natural to their tribes under ordinary temperatures, is obviously more than sufficient to boil the vegetable, or to roast the animal when dead. Now, this power of resisting temperature the living body owes to the performance of certain vital processes which are excited to extraordinary action under extraordinary circumstances. By the same power it is capable of bearing with impunity intense degrees of cold. In climates and seasons when the thermometer indicates a degree of cold much below zero, the temperature of the animal body continues almost unchanged, and all the functions of life go on without impediment or injury. Some of the lower animals may even be frozen and rendered quite torpid without the loss

of life. The common eel may be reduced to this condition and conveyed thousands of miles in a state of complete torpor, while it may be again restored to the full possession of activity and health, by the cautious application of warmth. And in whatever climate man himself has been able to live, or into which curiosity has led him to penetrate, there, wherever he has been able to trace a vestige of animal being, plants have equally been found flourishing in vigour and adorned with beauty.

Other classes of facts indicate a controlling power equally characteristic of the living body. Seeds endowed with vitality remain unchanged, under circumstances in which they would certainly be destroyed (that is, decomposed and resolved into their ultimate elements) were they destitute of the principle of life. They remain buried many thousand years deep in the bowels of the earth, yet when accident throws them to the surface, and they fall into a soil which is favourable to their vegetation, they immediately begin to develope properties which had lain latent for unknown ages, and spring into active life with all the vigour of a seed formed under our own eye. Hence in the neighbourhood of quarries new plants are continually making their appearance, which had never before been observed to grow near such places. Seeds pass uninjured even through the digestive organs of animals, exposed with impunity to the most powerful of all solvents of vegetable and animal matter, the gastric juice. And what is truly remarkable, irresistible as the action of that wonderful fluid is upon all dead vegetable and animal substance, it has no perceptible influence whatever upon any of those substances as long as they retain their vitality. No living being, when in the stomach of an animal, is acted upon by its gastric juice until the vitality of that being is destroyed. Hence worms are capable of living for an indefinite period in the stomach of animals, and are exposed with impunity to their gastric juice; nor is there any mode of destroying them, but that of introducing into the stomachs of the animal some substance which kills these parasitic creatures, and then they are easily expelled. The walls of the stomach during life are in constant contact with its own gastric juice, without receiving any injury from it; but it sometimes happens after death, that this fluid corrodes and eats through the very organ that formed it. The egg, like most other living beings, maintains a temperature considerably above that of the surrounding medium: by a delicate thermometer, its vitality, that is, its freshness, may always be ascertained; and as long as it is alive it resists putrefaction under degrees of heat and moisture which cause it to run rapidly into the putrefactive process as soon as it is dead.

The property of hybernation in animals, exceedingly curious in all the circumstances that belong to it, is truly wonderful in its preservative power —a power which maintains the existence of the animal, not only as well as if all its vital actions were in full operation, but, if the observations of some naturalists are to be credited, even under circumstances in which the animal could not live, were its ordinary vital actions in complete play. The state of hybernation itself seems to be produced in order to preserve the animal from the operation of temporary causes, such as states of temperature, climate, and so on, which would be fatal to it. While these states continue, the usual vital processes are either wholly suspended, or go on with an extraordinary degree of slowness: as soon as the former pass away, the latter renew their action, and the animal springs into life with renovated power, safe, during the whole period of its suspended animation, from the influence of physical agents, not only in their ordinary state of energy, but, as has been just stated, in an exordinary degree of intensity.

The loir, or fat dormouse, which in winter falls into a torpid state, illustrates what may be considered as the lowest degree of hybernation. These creatures possess so little animal heat that it scarcely exceeds the ordinary temperature of the air: their torpor ceases with the cold: a few degrees of heat, about ten or eleven, will reanimate them, and if they are kept during winter in a warm room, they will continue active the whole season; they will then move about, eat, drink, and sleep at the usual intervals, like other animals. When the cold approaches they roll themselves into a ball, and in this state may be found in winter in hollow trees, or clefts of rocks, or in holes in walls exposed to the south; they may be taken

and rolled about without rousing them; nothing, indeed, seems to awaken them from their lethargy but gradual heat; if exposed suddenly before a fire they die: resuscitation can only be effected by degrees. In this state, however, although deprived of the capability of movement, with the eyes closed, and in an apparent state of death-like indifference, they possess a feeling of pain when sharply inflicted: a wound or a burn causes them to contract, and to make a slight sort of convulsive leap, which they will repeat several times.

From experiments performed on this species in particular, among other lethargic quadrupeds, by A. M. Mangili of Pavia, it appears that its hybernating or lethargic state takes place only within certain ranges of temperature; that either too high or too low a degree of temperature prevents it from coming on; that the torpor is most profound when the temperature is at from 5° to 7° above zero, and that a more intense cold even revives the animal to activity. These experiments shew in the most beautiful manner how completely this singular condition, scarcely to be distinguished from that of death, is under the regulation and control of the vital principle, that principle inducing the state when the cold is at a certain degree, but preventing it from coming on, and even rousing the animal from it when it has actually supervened, if the intensity of the cold increase.

But if the accounts given by naturalists of the hybernating condition of certain birds be deemed worthy of credit, how much more wonderful must appear the preservative power of life, and how much more extraordinary the modifications of state in the same animal of which it will admit! That the cuckoo hybernates, and that, when accidentally found in its torpid state, it appears like a dead mass of matter; that it may be rolled about, or even struck with a considerable degree of violence without producing the slightest sign of sensation; that its respiration and every other manifest vital action seem to be wholly suspended, are well known facts. Equally familiar to us is the annual migration of swallows from our country and their regular return to it in the month of April; but it is not so generally known that some of these birds, probably the young and the feeble, remain the whole year in Britain, and as the winter approaches, retiring into the hollows of trees, the clefts of rocks, and the bottom of deep caverns, fall into a torpid state, and continue in a profound lethargy during the cold months. In the severer climates, the fact of their hybernation is still more abundantly attested; but the most extraordinary statement is that, in such countries, they precipitate themselves into the sea and into deep lakes and rivers, at the bottom of which they remain during winter in a state of profound torpor. If such accounts may be credited, and they are attested by authorities which can scarcely be questioned, how wonderful must be the action of the vital principle in preserving the life of an animal under circumstances so extraordinary, in an element which would certainly be fatal to it in a few minutes in its ordinary state; with its respiration suspended, its circulation stopped, and its blood—in what condition must we conceive this fluid to remain? If it coagulate, which it must do in a few seconds, unless under some counteracting and controlling influence, it can no longer be a living fluid, and how then can the animal possibly revive? But if it do not coagulate, if it remain alive, and therefore fluid, though at perfect rest, and exposed to such a degree of cold for this length of time, how striking an illustration would this most singular fact afford of the uninterrupted and enduring and efficient action of the vital principle, under circumstances which would seem absolutely incompatible with its existence even for a few moments!

Not less remarkably is the influence of this living power exemplified in the protection it affords the body from disease. It often happens, that causes which are injurious to the body, when they do not operate upon it with sufficient intensity utterly to destroy life, are still adequate to disturb its functions, and thus to occasion disease. Against the influence of such noxious agents the living body is endowed with a power of resistance which affords it complete security as long as its vital energies continue vigorous; but when these decline, the very causes which before made no sensible impression upon it, now prove fatal. Hence the weaker the body the more susceptible it is to the influence of physical agents, and the less it is capable of resisting the influence of those that are noxious. And when at length death does take place, how instantane-

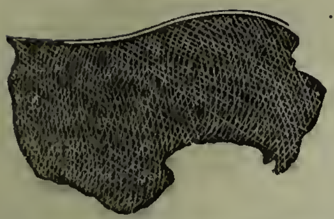
ous and how entire is the change which the body undergoes! During life, in a creature high in the scale of being, how graceful is the rounded form of the limbs, broken only by the undulations which mark the play of the muscles and which indicate their strength! How soft the balmy heat which pervades every part of the frame! How exquisite the variety, the rapidity, the exactness, the strength of the movements! The instant death seizes on this active creature, all its power of motion is at an end; its genial warmth is gone; its muscles become flaccid; the angles of its bones are prominent and sharp; its eyes lose their lustre; its countenance is without expression; its lips are motionless, and its cheeks livid. This livid colour passes rapidly to a blue, a green, a black: the flesh absorbs moisture; one part of it arises in pestilential exhalations, the remaining part becomes a liquid and putrid mass, and the work of destruction stops only when nothing remains of the body but a few earthy and saline particles, everything else being dispersed in air or carried off by water; having entered into new combinations or formed a constituent part of new beings. And the chemical affinities of the agents which produce these astonishing changes, agents which have surrounded the body from the first moment of its existence, why have they not always operated?—for the reason we have endeavoured to illustrate; because, in the former case, the body was alive, and therefore resisted and controlled the influence of these agents; in the latter case, life being extinguished, the body is in the condition of an inorganic substance, and is therefore instantly acted upon by them.

The manner in which physical and chemical changes are effected in inorganic bodies, is either by the change of place in their masses, or by the change of combination in the elementary particles of which they are composed. It is remarkable that life does not counteract the operation of the agents which produce these changes, as might at first be supposed, by retaining in one uniform position the identical particles of which the living body is formed; for no particle of the living body retains its relative position for any considerable time—no particle continues long in the body itself; all are in a state of constant mutation; old particles are every moment taken away; new particles are every moment supplied: it is by incessant motion among the integrant particles of the living body, not by rest, that its integrity is preserved; and that motion, for the most part, is internal. A circle of actions is established *within* the body, by which certain processes are accomplished which counteract decomposition and retain it in the peculiar condition which, as far as our observations go, is necessary to life. Thus, internal, or, as they are often termed, intestinal actions, counteracting the ordinary influence of physical agents, afford the first distinctive character of life.

2. The second is the power possessed by the living body of assimilating foreign matter to its own substance. The particles of which inorganic bodies consist are held together by mutual attraction: they increase by the juxtaposition of new particles, which are merely superimposed upon the pre-existing mass. The living body is endowed with the power of converting materials of different natures into one homogeneous substance, and of elaborating from that substance the various fluid and solid parts of which it is composed. The plant puts forth its roots into the soil, and abstracting the nutrient particles it finds, converts them into its own proper substance. The animal receives into the interior of its body the different substances from which it derives its nourishment; dissolves them; decomposes them; recombines their elements in new proportions and in different modes, and thus forms all the tissues and all the organs which anatomy displays as composing its structure.

3. A third character by which the living body is distinguished is derived from the peculiar disposition of the materials of which it consists: that disposition is always regular and determinate, constituting arrangement. This arrangement is termed structure; the process by which it is effected is called *organization;* hence the body in which it is found is said to be organized. The most simple, or the ultimate arrangement, in an organized body, as far as it is in our power to trace it, consists of an areolated and spongy substance, forming exceedingly minute cavities, in which the fluids are contained. Of this structure an imperfect conception may be conveyed by the annexed figure.

Fig. 1.



This areolated and spongy substance is disposed in layers: its fibres interlace and intersect each other in every possible direction; thus uniting, it forms tissues; tissues combine, and form organs; organs combine, and constitute the entire body.

We have thus arrived at three characters which distinguish the living body, namely, the power of resisting, within a certain range, the ordinary operation of physical agents; the power of converting matter of different qualities into its own proper substance, and the power of arranging the substance thus formed in a regular and determinate manner, denominated structure. There are two additional phenomena, which are equally distinctive of it: these relate to its origin and its termination.

4. It is a general law, that living beings derive their origin from pre-existing living beings, by a peculiar process, termed generation. The first origin of a new being is veiled in impenetrable mystery: its first indications of life, however, can, in general, be traced to what is termed a germ; that is, an organized substance, the product of the parent animal. Living bodies form, primitively, part of other living bodies from which they are subsequently detached; from these bodies they derive the degree of development which renders them capable of independent existence: it is the vital motion in the parent stock that communicates to the offspring its vital impulse: it is life that gives origin to life.

As this power of forming a being similar to itself, by which the species is perpetuated, is exceedingly characteristic of the living body, so its power to repair or to reproduce, by internal actions, parts of its own body which may have been lost, is scarcely less remarkable. In the lower animals, entire organs, when removed, are completely and rapidly regenerated. If one or more of the rays of the asterias (*fig.* 2) be destroyed, they are renewed with surprising rapidity. Blumenbach states that he cut away the entire eye of the water-newt, and that the organ was perfectly restored, only somewhat smaller than the other, in a short space of time.

Fig. 2.

All living beings have this power in a greater or less degree; but, for reasons hereafter to be assigned, the power is greatest in the most imperfectly organized.

5. The last character by which the living body is distinguished, is that of terminating its existence by the process of death. The vital energies by which the circle of actions and reactions necessary to life is sustained, at length decline, and finally become exhausted. Inorganic bodies preserve their existence unalterably and for ever, unless some mechanical force or some chemical agent separate their particles or alter their composition. But, in every living body, its vital motions inevitably cease, sooner or later, from the operation of causes that are internal and inherent. Thus, to terminate its existence by death, is as distinctive of a living being as to derive its origin from a pre-existing germ.

Such is the series of phenomena which we invariably find associated wherever there is life: such a series of phenomena is never found but in a state of life. The assemblage of these particular phenomena is expressed by the general term life. It is natural to conceive that these phenomena are attached to some permanent subject. We are almost irresistibly impelled to the adoption of such an hypothesis, in relation to every subject, physical as well as vital. We say that matter is the permanent subject of certain qualities, such as extension, divisibility, attraction, repulsion, and so on. We say that mind is the permanent subject of certain faculties, such as per-

ception, memory, association, reason. In like manner we imagine that there is a permanent subject, which we name the vital principle, upon which we conceive the phenomena of living beings to depend. But these permanent subjects, these substrata in which qualities are supposed to inhere, must be considered, so far as our real knowledge is concerned, fictions of the imagination. All that we really know are the ascertained phenomena; beyond these everything must, of course, be conjecture; and the most eminent men have fallen, and at this very time are constantly falling, into gross error, by not keeping the distinction here suggested steadily in view

Organized beings are divided into two great classes, vegetables and animals. The phenomena, we have hitherto stated, are common to both. There are characters by which they are distinguished from each other: these are derived from certain properties which are possessed by the one, but of which the other is destitute. Every living being must possess the power of assimilating foreign materials into its own substance; and, since it is a law of the vital economy that life springs from life only, it must be endowed with the further property of generating an offspring inheriting a nature similar to its own, otherwise every species of creatures would perish with the primitive race. The faculties of nutrition and reproduction must, therefore, be common to all living beings. Vegetables, accordingly, exercise these two functions, but to these their economy is limited. Animals, on the other hand, possess two additional faculties, namely, sensation and voluntary motion; from which superadded endowments they are said to be *animated*, and are therefore called animals. Thus, vegetables possess only one set of faculties: animals, on the other hand, are endowed with two kinds—first, those which they possess in common with vegetables, and which, accordingly, are called vegetative; or which, because they are essential to the maintenance of life in the individual, and to the perpetuation of it in the species, are sometimes denominated *vital;* these are, nutrition and reproduction: and, secondly, those which are peculiar to animals, but because they belong exclusively to this division of living beings, are termed *animal;* these are, sensation and voluntary motion.

Some ingenious men have inclined to the opinion that vegetables, no less than animals, possess sensation, and exercise spontaneous motion. There are vegetable phenomena which seem at first view to favour this opinion; but, on strict examination, it will be found that they really afford no support to it. The argument for the sensibility of plants is founded on certain movements which they exhibit, which are truly analogous to those of animals, and which it must be confessed have very much the appearance of spontaneity. The study of the vegetable economy furnishes numerous examples of such motions. The germ, and the radicle of the seed, invariably pursue each its proper direction, although the seed be sown in an inverted position. The plumula always directs itself upwards, while the radicle as certainly strikes downward into the ground. "Several years ago," says Dr. Perceval, who is one of the most ingenious advocates of the perceptivity of plants," whilst engaged in a course of experiments to ascertain the influence of fixed air on vegetation, the following fact repeatedly occurred to me:—A sprig of mint, suspended by the root, with the head downwards, in the middle glass vessel of Dr. Nooth's machine, continued to thrive vigorously, without any other pabulum than what was supplied by the stream of mephitic gas to which it was exposed. In twenty-four hours the stem formed into a curve, the head became erect, and gradually ascended towards the mouth of the vessel, thus producing, by successive efforts, a new and unusual configuration of its parts. Such exertions in the sprig of mint to rectify its inverted position, and to remove from a foreign to its natural element, seems to evince volition to avoid what was evil, and to recover what had been experienced to be good. If a plant in a garden-pot be placed in a room which has no light except from a hole in the wall, it will shoot towards the hole, pass through it into the open air, and then vegetate upwards in its proper direction. Whether the pond in which it grows be deep or shallow, the water-lily pushes up its flower stems till they reach the open air, in order that the *farina fecundans* may perform without injury its proper office. About seven in the morning, the stalk erects itself, and the flowers rise above the surface of the water; in this state they continue until four in the afternoon, when the stalk becomes re-

laxed, and the flowers sink and close. The sensitive plant contracts on the slightest touch, and immediately folds up its leaves. The flowers of a great variety of plants alter their direction according to the circumstances in which they are placed. A hop-plant, turning round a pole, follows the course of the sun, from east to west, and even dies if forced into an opposite line of motion. The regular movements by which the sun-flower presents its splendid disk to the sun, have been the subject of universal admiration, both in ancient and modern times:—

> The lofty follower of the sun,
> Sad when he sets, shuts up her yellow leaves,
> Drooping all night; and when he warm returns,
> Points her enamour'd bosom to his ray.

The lateral leaflets of the *hedysarum gyrans* present a constant alternation of elevation and depression, and this regular and successive movement is conceived to be connected with the function of respiration. The stamina of the *berberis vulgaris*, and of several other plants, move towards the stigma, in a manner which has struck every observer with its similarity to spontaneous motion. The roots of plants which proceed in pursuit of proper nourishment, and which alter their course the moment they approach a situation which would be injurious to them, afford examples which still more strikingly resemble spontaneous movements. If a wet sponge be placed near a root exposed to the air, the root will direct its course to the sponge: if the place of the sponge be changed, the root will vary its direction. The claspers of briony shoot into a spiral, and lay hold for support of whatever may come in their way. If, after completing a spiral of three or four rounds, they meet with nothing to sustain them, they set out afresh in search of support, by altering their course.

But, curious and interesting as many of these movements are, they are inadequate to prove that vegetables possess either sensation, that is, sensation attended with consciousness, or voluntary motion. They are referable to a power possessed in common by plants and animals, namely, the power of contracting on the application of a stimulus. Contractility is truly a vital power: it is possessed only by an organic being; it is possessed in common by both classes of organic beings; but it is constantly exercised, even in the animal, without consciousness, and therefore of necessity without volition: whence the exercise of it in the vegetable cannot possibly prove that it is attended in this lower order of beings with the possession of consciousness. But that the vegetative functions are performed without consciousness, we have a still more striking proof in ourselves: for man exercises both classes of functions, the vegetative and the animal. By observing what passes within ourselves, we see that there is no connexion between mere vegetative life and sensation: the latter is a totally distinct and higher faculty, superadded to the former. We are conscious that we live; we are not conscious of the operation of the vegetative faculties by which we live. Of all the processes by which the aliment is converted into blood, and the blood into the proper substance of the body, complicated as the processes, and numerous and incessant as the motions are by which they are performed, we are wholly insensible. There can, therefore, be no reason to suppose that these functions are attended with consciousness in the vegetable, in which all the processes are so much more simple. No motions of the vegetable indicate spontaneity more strikingly than the motions by which a wound, attended with the loss of substance, is healed in the animal body. In this process new fibres are formed, which arrange themselves, not only as if they were animated and intelligent, but the degree of wisdom with which they are disposed is perfect: yet all this is effected, not only without our having the least knowledge of the mode in which it is done, but even without our being sensible that it is done at all.

The distinctions we have endeavoured to establish between animal and vegetable bodies remain therefore unsubverted; but, besides these, which may be considered as primary, there are other characters by which they are distinguished, which, though not so essential, are still very striking.

Vegetables in general are separable by a horizontal line into two parts, one of which ascends and is contained in the air; the other descends and is contained in the earth. Animals in general are separable by a vertical line into two equal halves, whence their body is said to be symmetrical, that is, divisible by a median and vertical line into two equal and similar lateral portions. Vegetables consist of an areolated tissue which is often firm, hard, and unyielding; of

ascending and descending vessels; of spiral tubes; and of peculiar fusiform bodies termed closters. Animals consist of an areolated tissue, which is always soft and elastic, and which for the most part, at least in all the higher animals, is moulded into vessels which perform a proper circulation. The organs of vegetables, few and simple, are placed on the exterior of the body: the organs of animals, extremely numerous, often wonderfully complicated, are almost always placed in the interior of the body. Vegetables consist of three ultimate principles only, namely, carbon, oxygen, and hydrogen: animals consist of four ultimate principles, namely, carbon, oxygen, hydrogen, and azote. Some few vegetables, it is true, contain a minute quantity of azote, but even in these this substance is confined to particular parts of the plant, and does not enter as a constituent element into its composition.

The simplicity of the structure of the vegetable exhibits a striking contrast to the complexity of the animal organization; yet nothing is given to the animal which its mode of life does not absolutely require. For the simple functions performed by the vegetable, a simple structure is sufficient; for the complicated functions exercised by the animal, complicated organs are indispensable. Nature is never prodigal and seldom profuse. The addition of the peculiar faculties of the animal rendered a modification of the common or vegetative faculties absolutely necessary—a modification which could not be effected without increasing the complexity of the mechanism. The vegetable, fixed to the soil which contains its nourishment by its roots which absorb that nourishment, requires no special organ for holding and accumulating its alimentary matter. The animal, not being fixed to the soil, endowed with the power of locomotion, constantly changing and delighting to change its place, must transport with itself the nourishment necessary for its support. Hence the necessity of a special organ for containing its aliment: hence the necessity of modifying its mode of nutrition. That modification is made, in general, by furnishing the animal with an internal cavity, within which it deposits the substances proper for its nourishment. In the coats which form the walls of this cavity are placed the orifices of vessels which absorb the nutrient particles. This cavity, with its contents, is to the animal what the soil is to the vegetable, and its absorbing vessels constitute the internal roots of the animal.

A second modification, equally indispensable, arises out of the necessity of conveying the nutritive matter to different parts of the body. A considerable force is required to propel the nutritive fluid over its extended surface. For the supply of this force new expedients must be adopted: there must be a circulation of the nutritive fluid: for this purpose vessels must be furnished to contain the fluid, and an engine must be constructed capable of generating a force adequate to communicate to it the requisite impulse. It is easy to see that a communication must next be established between the digestive organ and the vessels which carry on the circulation. And thus, if we were to trace the animal organization to its highest state of complexity, we should perceive that that complexity was absolutely requisite for the due exercise of the higher faculties with which these higher beings are endowed.

The matter of which organic bodies consist is precisely the same as that which is found in the inorganic: it is not a difference in the nature of their component particles, but a difference in their arrangement, that constitutes the essential distinction between those two great classes: the very name of organic bodies points to this fact; for they are denominated organic, because the matter of which they consist is invariably arranged in a peculiar manner termed organization. Dead, or inorganic matter, arranged in this peculiar manner, and modified according to certain unknown laws, becomes organic: what the modification is by which inorganic is converted into organic matter we are wholly ignorant.

It has been stated that the ultimate elements of vegetable bodies are reducible to three, namely, oxygen, hydrogen, and carbon, the former existing in a gaseous, and the latter in a solid state. The ultimate elements of animal bodies are four, namely, oxygen, hydrogen, carbon, and azote. In the animal body are also found the following elementary or simple substances, phosphorus, calcium: these are found in very considerable quantity: sulphur, iron, manganese, silicium, iodine, chlorine: these exist in minute quantities: and to this list it may, perhaps, be proper to add caloric, light, the electric and the magnetic fluids.

Having premised these fundamental observations relative to the nature, the properties, and the distinctions of inorganic bodies, and of vegetable and animal beings, we proceed to give a more particular account of the structure and functions of the animal body.

If we examine an animal high in the scale of organization, we are struck with the variety of its component parts and with the complexity of their structure. By analytical investigation, it is ascertained that these parts, various and complex as they appear, consist only of the elementary bodies which have been just enumerated, and which are called elementary, because they are not capable of reduction, by any known process, into substances that are more simple. These inorganic substances combine together in different numbers and different proportions, under the unknown circumstances which constitute the condition of life, and thus form all existing varieties of organic matter.

By synthetical investigation, it is ascertained that some of these elements combine together in definite proportions, namely, three and three, four and four, and so on: the result of such combinations is the formation of what are termed the Proximate Principles of animals. A proximate principle is the primary combination of two or more of the elementary substances in definite proportions. Of these the chief are albumen, fibrin, gelatin, mucus, casein, olein, urea, uric acid, osmazome, &c.

The component substances of the animal body are invariably disposed in two forms—fluids and solids. The fluids are contained in the solids: both are mutually dependent; both possess an analogous composition; both are in continual motion and pass without ceasing from the one into the other. Every animal consists of a union of both; that union is indispensable to animal life.

Of the Animal Fluids.

The absolute quantity of the fluids contained in the animal body it is difficult to ascertain, because it varies according to varying circumstances, and in the same animal is different at different periods of life, and according to the state of health and of disease. Invariably the younger the animal the greater the quantity of the fluids. The embryo of all animals when it first becomes appreciable by the senses, appears to be almost entirely fluid. As it grows and is developed, solid parts are gradually added. The quantity of the fluids successively diminishes until the animal arrives at mature age.

Many experiments have been made to ascertain the relative proportion of the fluids to the solids in the human body. Chassier placed a dead body, weighing 120 lbs., in a heated oven: after desiccation for several days he found the weight reduced to 12 lbs. In mummies, in which the abstraction of the fluids is complete, there is always found a remarkable diminution of weight, some of them not weighing more than 7 lbs. The proportion of the fluids to the solids at the adult age in man is estimated, according to the lowest computation, as 6 to 1, and according to the highest, at 10 to 1.

The fluids differ greatly in their density. Some exist in the state of gas: others in the state of vapour: some are extremely thin and transparent, as that of the serous membranes, or the membranes which line the great cavities of the body, as the thorax and abdomen: others possess considerable consistence, as some of those secreted by the mucous membrane—the membrane, for example, that lines the air-passages. Some exist in exceedingly minute quantity, as the delicate fluid contained in the internal organ of hearing: others form a large part of the bulk of the body, as the blood. Some are intimately combined with the animal solid; others are contained in minute, delicate, solid areolæ: some are poured out on the surface of solids, particularly of membranes; others are contained in membranous bags or reservoirs, and a great number are contained in distinct vessels.

They are composed for the most part of water, in which the various component substances of the body are held in solution. It is a very curious fact, that many of them consist of masses of globules. These globules can in general be seen only by the microscope. They were discovered almost as soon as the microscope was invented, but the observation was very generally neglected until recently. For reasons which can scarcely be explained at present, the fact is found to possess great interest and importance; and, at this very time, some of the most intelligent and skilful physiologists are engaged in investigating the subject, so that it is probable that many things, which must now be considered as doubt-

ful, will soon be determined. These globules are found principally in the nutritive fluids, namely, the chyme, the chyle, the lymph, the blood, and, in some of the secreted fluids, as milk, pus, and so on.

The properties of the fluids are either physical, chemical, or vital. There would be no utility in exhibiting a collective view of these physical properties : it will be better to consider each separately, when the more important fluids are treated of in detail. Their chemical properties are very important. All the great actions of life are intimately connected with them. Their influence over all the processes which are constantly going on in the economy is so great, that if the body may be called a machine, as, from the admirable adjustment of its various parts, it may be termed with striking appropriateness, it may at least with equal truth be denominated a laboratory, in which the most important and extensive chemical actions are taking place every instant. In general the chemical composition of the fluids is the same as that of the solids : both contain the same proximate principles—albumen, gelatin, fibrin, and so on ; and in the living body there is a continual transformation of fluids into solids, and of solids into fluids. Whatever may be the case with the other fluids, the blood at least exhibits phenomena which are perfectly analogous to those of the living solid. If blood be taken from an artery or vein, and kept at rest at the same temperature which it possesses in the living body, after a certain time it undergoes the process of coagulation ; that is, it separates into several distinct portions, some of which are fluid and some solid : it is now no longer a fluid substance ; it dies ; and this change into a substance partly fluid and partly solid, takes place, it is conceived, subsequently to its death, and in consequence of its death, because, as long as it continues to be a living fluid in a living vessel, it preserves its fluidity. Nor does it owe the maintenance of its fluidity to its circulation ; to mere motion at a given temperature : for experiments have been performed, in which the circulation of the blood has been imitated in artificial tubes, kept at the natural temperature of the blood ; but, even under these circumstances, this fluid has always coagulated, just as if it were in a state of perfect rest : the inference is, that the blood maintains its fluidity in the living body, in consequence of its being endowed with the property of life. The blood may be shot dead instantaneously, as it is by a stroke of lightning. It is also subject to manifest disease, as is strikingly exemplified in certain cases of poison, in certain kinds of fever, and in the remarkable disease termed scurvy; but nothing in the slightest degree analogous to the phenomena of disease can be exhibited by any body which is not endowed with life.

The fluids have been differently arranged, from time to time, according to the different doctrines which have successively prevailed in the schools. The ancients conceived that there were four elements, out of which every substance, inorganic and organic, was formed. In conformity with this notion, they divided the fluids of the animal body into four principal humors : namely, the blood, the lymph or pituita, the yellow bile, and the black bile. While it is difficult to form a perfect arrangement, physiologists have suggested different principles as the basis of division. i. Some have proposed to found it on the use which the fluids serve in the economy. According to this principle, the fluids have been divided into primary and secondary. The primary are the alimentary, or the recrementitious ; these include the fluids, which conduce to the nutriment of the body. The secondary, or the excrementitious, comprehend those which are secreted, in order to be carried out of the body ; that is, in order to remove from the system principles which are either useless or noxious. ii. Others have proposed to class the fluids according to their *mode* of formation. Hence they divide them into—1. Chyme, Chyle ; 2. Lymph ; 3. Blood ; 4. Fluids of perspiration, and exhalation ; 5. Follicular fluids ; 6. Glandular secretions.—iii. A third suggestion is to divide them into four great classes : namely, 1. Those which form the blood ; 2. The blood itself ; 3. Those which are formed from the blood ; 4. Those which are returned to the blood from all the parts of the body. This arrangement is simple and comprehensive, but perhaps the most convenient is that which is founded on the chemical composition of the fluids. iv. According to this principle, the fluids are arranged into the eight following classes :—1. The aqueous ; 2. The albuminous ; 3. The mucous ; 4. The gelatinous ; 5. The fibrinous ; 6. The oleaginous ; 7. The resinous ; 8. The saline.

The advantages of this classification are, first, that for every fluid an appropriate place is readily found; and, secondly, that as all the fluids are secretions, this arrangement will prove useful in treating of the function of secretion, and in enabling us to exhibit a comprehensive view of the products formed by that process.

Of the Animal Solids.

The solid parts of the animal body are derived from the fluids. They are formed out of them by a peculiar process, hereafter to be described, termed secretion. After the solids are once formed, they depend for their integrity upon a continual supply of the fluids.

In the human body, the proportion of the solids to the fluids has been already stated to be about one part in nine or ten. The solids are composed of the same physical substances as the fluids; are reducible by analysis to the same chemical elements, and form, by the primary combination of these elements, the same proximate principles.

Every animal solid is either concrete or fibrous: that is, it is either without arrangement, like jelly or glue, or it is disposed in the form of minute threads, which are termed fibres. When arranged in different structures, these fibres either retain the form of threads, or are disposed in minute plates or laminæ: hence, whatever animal structure be examined, it is found to be either fibrous or laminous.

In combining to form the different animal structures, the solid parts are disposed in a great variety of modes. Of these, the chief are into filaments, fibres, tissues, organs, apparatus, and systems.

The filament is the elementary solid. A fibre consists of a number of filaments united together. A tissue is composed of fibres, arranged in a particular order. An organ is a compound body, consisting of a specific arrangement of different tissues. The most simple organ is always a very compound body. If we examine a muscle, for example, we find that it consists first of the muscular fibre; then of a distinct envelop, formed of a particular tissue, the cellular, and next of a peculiar substance termed tendon. In like manner a nerve consists of a substance of a peculiar nature, constituting the nervous matter, which is always inclosed in a distinct membrane, termed the neurilema. The most simple gland consists of a congeries of many different vessels, united by cellular tissue. The eye, the ear, the viscera, are exceedingly complicated organs, consisting of many different tissues, arranged in many different modes. Every organ performs a specific action, or exercises, as it is termed, a particular function. Life is always observed in connexion with the exercise of these functions: hence the organs are termed the instruments of life.

An apparatus is an assemblage of different organs, all of which concur to the production of some definite object. The apparatus of digestion, for example, consists of the organs of mastication, of the organs of deglutition, of the stomach, of the duodenum, of the pancreas, of the liver, of the lacteal and absorbent vessels, and of the glands connected with these vessels, to which ought in strictness to be added the lungs. Numerous and different as these organs are, varied and even opposite as is their action, yet they all concur to one end, namely, the formation of blood. The organs which compose an apparatus, individually considered, may be exceedingly different in their structure and function. They may have nothing similar in organization; the products of their action may be of opposite natures; but they are associated together in one class, on account of their conjoint operation in the production of some common end.

A system, on the contrary, is an assemblage of organs, all of which possess the same, or an analogous structure. Thus all the bones of the body, however different in figure, in magnitude, in disposition, have one common structure: hence they are all associated in one great class, which is termed the osseous system. In like manner, whatever be the form, disposition, or action, of the different muscles, they all possess one common structure, and therefore are arranged into one class, termed the muscular system. For the same reason, all the vessels of the body are classed together under the name of the vascular system; all the ligaments under the name of the ligamentous system, all the nerves under that of the nervous system, and so on.

Some of these tissues are so extensive, are found in so many parts of the body, and enter in so large a proportion into the composition of all the different organs, that they are distinguished by the appellation of common. Thus phy-

siologists speak of the common cellular tissue, of the common integuments, or the common dermoid tissue, or skin, and so on.

Taking this view of the animal body, which is a truly physiological view, we may say, that, excepting in the very lowest animals which appear to consist of a homogeneous substance similar to jelly, it may be considered as an aggregate formed of a number of organs; that each organ is itself composed of a variety of tissues, and that each tissue is more or less common to all the organs.

Varied and almost innumerable as the different solids at first view appear in the higher animals, as in man, yet, when attentively examined, it is found that they may be all included in the following substances, namely, bones, with their cartilages and ligaments, which may be considered as appendages to the bones; muscles with their tendons; membranes of various descriptions; sacs of different structures; vessels of different kinds, and nervous matter. There is no solid of the body which may not be comprehended under one or other of these substances. And these substances again, widely different as they appear both in composition and structure, may all be reduced by careful and accurate analysis to three, namely, the Cellular, the Muscular, and the Nervous Tissues.

1. *Of the Cellular Tissue.*

Of all the animal solids the cellular tissue is the most simple in structure, the most abundant in quantity, and the most extensively diffused. It enters as a constituent element into every other solid. It composes the main bulk of bones; the strength, and hardness of these firm and solid bodies depending on an earthy matter deposited in cells formed of cellular tissue. It affords an external sheath to every muscle; it is interposed between every fibre, of which every muscle consists; it incloses in a distinct envelop every nervous fibre; it composes almost the entire bulk of tendon, ligament, and cartilage; it enters largely into the composition of hair, nails, and other similar parts connected with the surface of the body. The enamel of the teeth is said to be the only solid in which it cannot be detected. It unites together all the different parts of the body; it fills up all the intervals between them. Were it possible to remove from the bones their earthy particles, and from the soft parts the muscular fibres, the nervous matter, and the fat; were it possible at the same time to empty the vessels and to evaporate the fluids, the body would remain nearly of the same size, and be sustained nearly of the same form by means of this substance alone. It may therefore, be considered as the basis to which all the other parts of the body are attached; as the mould into which all the other kinds of matter are deposited.

When examined with the naked eye, and gently distended, this substance is found to be composed of fibres or threads of extreme delicacy, finer than the finest cobweb. These fibres intersect each other in all directions, so as to leave between them minute spaces which are termed areolæ, or cells. *(Fig. 1.)*

It is from this cellular appearance that the tissue derives its name. But this cellular arrangement disappears immediately when the distension is discontinued. Without mechanical distension there is no appearance of cells either in the living or the dead body. The fibre itself is solid. It was to demonstrate this, in opposition to the opinion of Boerhaave, who conceived that the ultimate fibre is a vessel, that Haller engaged in those laborious investigations which have made anatomists and physiologists so intimately acquainted with the structure and distribution of this substance. The result of the researches of this celebrated physiologist was the establishment of the fact, that the basis of the animal frame is a solid fibre to which the vessels are added as distinct appendages.

Of the cellular tissue are composed—1. membrane; 2. bones; 3. the sheaths which inclose the more tender and delicate structures; 4. the substance by which the different parts of the body are united together; 5. the substance by which the interstices between the different parts are filled up. Of all these substances, by far the most extensive and important is membrane. The great bulk of the animal solids consists of membrane, that is, of cellular tissue arranged in the form of membrane. 1. Membrane forms the general covering of the body, lining every part, both of its external and internal surfaces. 2. It affords a particular covering for its individual structures. 3. It lines all the cavities in which the principal organs are situated. 4. It composes the principal part of all vessels. 5. It forms what is termed the parenchyma, or the solid part of all the viscera. 6. It constitutes the main bulk

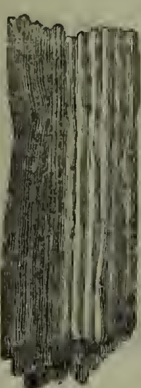
of all glands, whether those which are appropriated to the office of secretion, or those which are attached to the absorbent system.

Membranes are divided into different kinds, each of which performs distinct and appropriate offices in the economy. 1. Serous membranes; those which comprise all the sacs or shut cavities of the body, such as those of the chest and abdomen. 2. Mucous membranes; those which line all the air-passages; compose all the air-cells of the lungs; invest the whole track of the alimentary canal from the mouth to the anus, and thus form a principal part of the extensive and important organs of respiration, digestion, and excretion. 3. Fibrous membranes; those which compose tendon, aponeurosis, ligament, and so on. However widely many of these substances differ from each other in their general aspect and even in their intimate structure, yet that they are all modifications of cellular tissue, the evidence is so complete, that few anatomists or physiologists of the present day dispute it; and recent investigations have elicited new facts which directly prove the correctness of the opinion.

2. *Of the Muscular Tissue.*

The second tissue, which, on an analysis of the animal solid, is found to enter into the composition of the body, is the muscular. This tissue consists of a substance of a peculiar nature, which is arranged in the form of fibres of extreme delicacy. When examined by the naked eye, and taken in its most recent state from the dead body, these fibres appear soft, reddish coloured, solid, of various diameter, placed parallel and close to each other (*fig.* 3).

Fig. 3.

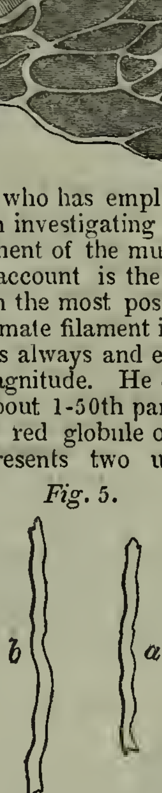


The musular tissue is arranged in two different modes; first, in the masses properly termed muscles, and, secondly, in a thin membrane-like expansion, denominated muscular coats. Proper muscles are composed of filaments (*fig.* 5): the aggregation of a number of filaments forms what is termed a fibre (*fig.* 3): fibres are collected into small bundles which are called fasciculi (*fig.* 4).

Fig. 4.

Prochaska, who has employed incredible labour in investigating the mechanical arrangement of the muscular fibres, and whose account is the most exact, maintains in the most positive manner, that the ultimate filament is discernible, and that it is always and everywhere of the same magnitude. He computes its size to be about 1-50th part of the diameter of the red globule of the blood. *Fig.* 5 represents two ultimate filaments; *fig.* 3 represents a number of filaments united together to form a fibre; *fig.* 4 represents numerous fibres united together, the whole forming a fasciculus.

Fig. 5.



Other anatomists maintain that it is only the imperfection of our senses and instruments which leads us to imagine we can perceive an ultimate filament. They suppose that the division of the filament does not stop where it seems to us to terminate, and that if our vision were improved, we should see that it still

goes on dividing and subdividing indefinitely.

The ultimate filament, as far as has yet been observed, is destitute of any cellular covering; but every fibre is inclosed in a distinct cellular sheath (*fig.* 6):

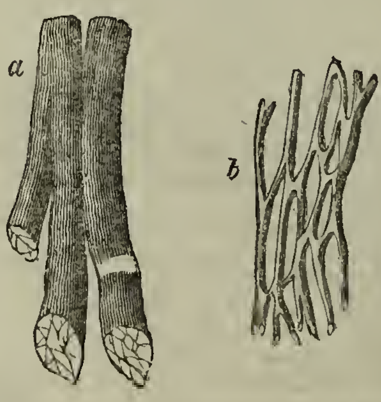
Fig. 6.

a, representing the fibres covered by the sheath; *b*, the fibres with the sheath removed.

every fasciculus is also inclosed in its own envelop (*fig.* 4); and lastly, the muscle itself is invested with a separate cellular coat which covers it completely at every point, excepting where its ends are attached to the bones.

The muscular fibres which are disposed in the form of a membranous expansion, and which constitute the muscular coats, appear to the eye to be very different from proper muscles, but they only, or at least chiefly, differ in the mechanical arrangement of their fibres: the natnre of both is precisely the same. Their fibres, instead of being collected into fasciculi, are disposed in layers, and instead of being parallel they interlace (*fig.* 7, *a*); and according to Prochaska even anastomose, that is, join each other by a union of substance (*fig.* 7, *b*).

Fig. 7.



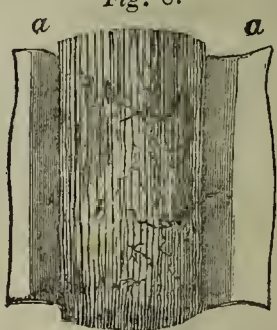
3. *Of the Nervous Tissue.*

The third tissue, into which the animal solid is resolvable, is the nervous. The nervous tissue consists of two substances, which, as far as the eye can distinguish, appear to be entirely distinct from each other. The one is sometimes named, from its colour, cineritious or grey; from its position, cortical; and, from its consistence, pulpy or gelatinous. This last is its most important character. It appears to be composed, for the most part, of a congeries of blood vessels. The other substance is termed white or medullary. It is of firmer consistence than the pulpy. The peculiar matter of which it is composed is arranged in the form of minute and delicate fibres. In every part of the nervous system which constitutes a distinct nervous apparatus, both substances are conjoined. Neither the pulpy nor the fibrous alone forms a distinct organ: the union of both is necessary to constitute an instrument capable of performing a specific function.

When the nervous system first begins to be apparent in the lower animals, it consists only of minute and exceedingly delicate threads. In all the more perfectly organized animals, the nervous substance is disposed in four different modes, forming four distinct parts or organs, namely, nerves, ganglia or appendages to particular nerves, the spinal cord, and the brain. Of the three latter organs, which are merely particular arrangements of the common mass of nervous matter, we shall speak more particularly when we treat of the functions of the nervous system, the plan to be observed in this paper being to precede the account of every function with a description of its apparatus.

A nerve is a cord of a white colour (*fig.* 8, *b*). It is composed of fibres of

Fig. 8.



a a, which represents the sheath of the nerve reflected.

nervous matter (*fig.* 9). These fibres, as soon as they become visible to the

Fig. 9.

naked eye, are perceived to differ in size from that of a hair to the finest fibre of silk. These fibres unite into bundles, which, as in muscle, are called fasciculi. The fasciculi uniting, form the cord to which the name of nerve is given. As in the muscle, the ultimate filament appears to be destitute of any cellular covering: but every fibre is inclosed in a distinct sheath, of exceedingly delicate cellular tissue. In like manner, every fasciculus is enveloped in a similar sheath; and, lastly, the cord itself is inclosed in its own cellular envelop (*fig.* 8 *a. a*). The cellular covering of the nerve is termed its neurilema.

It will be shown hereafter, that in the vascular system, either all the vessels proceed from one large trunk, which goes on progressively to divide and subdivide, until its branches become so minute as to be invisible; or, on the other hand, that they arise by numerous and invisible branches, which unite to form larger and larger vessels, until they ultimately constitute only a few trunks. The muscular and nervous filaments never divide and subdivide in this manner. It is the opinion of the most eminent anatomists, that there is a diameter beyond which they no longer diminish. That diameter they maintain is quite uniform in each. According to Fontana, the ultimate nervous filament is about twelve times larger than the ultimate muscular filament. This accurate observer represents the primitive nervous filaments as placed close and parallel to each other, similar to those of the muscles (*fig.* 8 *b*): and with his account, in general, the descriptions of Prochaska, Monroe, and the more recent dissections of Reil, agree in every important particular. Reil is quite positive in stating that the ultimate nervous filament is visible. Probably the more correct statement is, that there is a filament of a certain diameter, beyond which no means hitherto employed have succeeded in tracing its subdivisions. Reil agrees with Fontana in representing the ultimate nervous filament as much larger than the muscular.

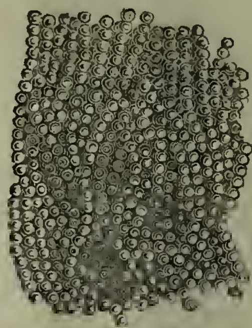
Of the Elementary Structure of the Animal Solids.

Hitherto we have described the structure of the primitive tissues only as far as they are visible to the naked eye. Thus far the agreement in all the essential points, in the descriptions of the most able observers in all ages and countries, is truly remarkable. The study of the elementary structure of these tissues opens a vast field of inquiry of great interest and importance, in which the labourers have hitherto been comparatively few; and their researches, made at distant intervals, and neither repeated so often nor carried so far as is requisite to ascertain the truth, have been attended with less satisfactory results. Investigations of this nature are attended indeed with peculiar difficulty. They require unwearied perseverance, extreme accuracy, great patience, and a dexterity with the hand united with a delicate discrimination of the eye, that belong to few, and the requisite use of which rare endowments

can be acquired only by long practice. Nor could such investigations be successfully pursued at all, did we not possess the means of magnifying the bulk of the object examined many hundred times beyond its real volume. Without doubt the microscope is an instrument in the use of which much caution is required; but that, when care is taken to guard against its sources of fallacy, it is capable of communicating real and valuable information, it were idle to dispute. It is remarkable, that one of the very first results of the employment of the microscope on its discovery was the detection of the globular structure of the primitive tissues of the animal body. Lewenhoeck, who, about the middle of the seventeenth century, applied the microscope to the examination of the different tissues of the human body, states expressly, that the ultimate filaments of which they are composed, are formed of globules of extreme minuteness. "Having exposed them (the ultimate muscular filaments) to my microscope," he says, "I saw to my wonder that they were made up of very small conjoined globules, which, in smallness, seemed to surpass all the rest; this I took notice of frequently." He adds, "I have used several methods to see the particles of these carneous filaments, and have always found that they are composed of such parts to which I can give no other name than a globule." This statement was regarded with great distrust: it was, however, confirmed by many able observers; but from that period to the present, at different intervals, it has been the subject of controversy, and the controversy continues to the present day. We have already stated, that the subject is at this very time engaging the attention of the most distinguished physiologists of Europe, and their researches will probably, at no distant period, ascertain the truth beyond reasonable doubt. In the mean time, we may give, in a few words, the results to which the most careful microscopical observers think they have arrived.

If the cellular tissue, when in a state perfectly natural, having been subjected to no preparation capable of altering its properties, be examined with a microscope of high magnifying powers, it appears to consist entirely of minute particles, of a globular form (*fig.* 10). These globules are arranged in irregular series, forming lines of different lengths, which take every possible direction, and intersect each other in every possible manner. All these circumstances are represented in *fig.* 10. It is remarkable, that from whatever part of the body the tissue be taken, the arrangement of the elementary globules, and their diameter, appear to be uniformly the same. That diameter is estimated at about the $\frac{1}{8000}$th part of an inch.

Fig. 10.

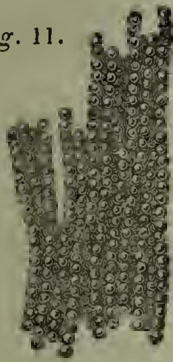


It is a very curious and interesting fact, that an examination of this tissue in the inferior animals, especially in the four classes of the vertebralia, has led to the discovery, that in all the tribes of the mammalia, in birds, in reptiles, in fishes, it is composed of globules, which have precisely the same general appearance, and which are exactly of the same magnitude. Subsequently, the examination has been extended to invertebrated animals, in all of which this tissue presents the same globular structure, with this difference only, that while the greater number of the globules are of the same bulk as in the vertebrated animals, they are mixed with others of a larger volume, it is supposed because these larger globules consist of a union of several of the elementary.

The elementary structure of the muscular tissue has been examined with the like care, and with the same apparent result. In this tissue also, the ultimate filaments appear to consist of globules: these globules are arranged in similar linear series; but the direction of the series is always different (*fig.* 11); in the muscular tissue the direction is invariably parallel. The fibres never intersect each other, like those of the cellular tissue, and this is the only discernible difference, for they are of the same figure and magnitude as the cellular. The same curious fact has been observed with regard to the uniformity of the structure of this tissue in all the inferior animals, and the identity

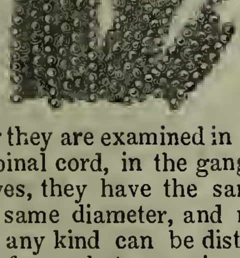
of the structure with that of the same tissue in man. The figure and diameter of the globules, and the parallel direction of the linear series, are the same in whatever creature they are examined.

Fig. 11.



Whatever doubt may be entertained, and whatever controversy may be agitated respecting the accuracy of these observations, in relation to the cellular and the muscular tissues, few examiners have called in question the globular structure of the nervous tissue. This structure is, probably, more visible in this than in the other tissues, because on account of its more soft and delicate texture it is more transparent. All the physical characters of the globules of the nervous are identical with those of the cellular and muscular tissues (*fig.* 12).

Fig. 12.



Whether they are examined in the brain, in the spinal cord, in the ganglia, or in the nerves, they have the same figure and the same diameter, and no difference of any kind can be distinguished in them, from whatever animal the specimen under examination be taken.

The general conclusion deducible from these series of observations is, that every animal solid consists of molecules, all of which possess a determinate figure and a uniform magnitude; and that these constitute the elementary particles, by the various combination of which all the tissues of all animals are composed. Supposing the correctness of these observations to be established, we might say, that a globule of about the diameter of the $\frac{1}{8000}$th part of an inch is the elementary organic molecule, of which every solid of every animal body is composed, because the analysis of every such solid might be carried on until we come to such a globule, but no further, at least by any instrument we at present possess. This globule might, therefore, be considered as the elementary organized corpuscle. Thus it would appear, that from the zoophyte up to man there is in the structure of all the different tissues not only a most striking similarity, but an absolute identity. We know, from the study of her laws, the simplicity of the means by which nature works; but these discoveries show the simplicity of the material with which she constructs the most varied of her productions, and renders that variety, infinite as it is, still more wonderful and admirable.

The result of the preceding researches suggests the further inquiry, whether the globular form which has been described be peculiar to matter assimilated to living beings, and consequently depend on the influence of life; or whether it be referable to the influence of laws purely physical, in consequence of which certain substances assume this form whenever they pass from the solid to the fluid state, in the same manner as salts in crystallizing are arranged in determinate figures. The experiments which have hitherto been made relative to this subject favour the opinion that it is the result of physical laws. Of these, one of the most remarkable is that performed by Prevost and Dumas. By the action of electricity, fluid albumen is converted into a white coagulum. On examining with the microscope the coagulum thus formed, these physiologists found that it abounds with globules precisely similar to those of the blood when deprived of its external envelop, and to those contained in serum, milk, and pus. They observed also, that these globules showed the same disposition to form series, or aggregates, as in the primitive tissues. Dr. Edwards has further established, by experiment, that the same phenomenon takes place whenever the coagulation of albumen is effected by the action of heat or of chemical agents; that when the serum of the blood, which

always contains in its fluid state a considerable number of globules, is coagulated either by evaporation or by the addition of an acid, or of alcohol, a prodigious quantity is formed; that the same result is obtained by the solidification of the vitreous humor of the eye, of the mucus secreted by the snail, and of that which surrounds the eggs of the frog; that the same is the case with gelatine; that if a small quantity of acetic acid be added to the filaments which compose the substance of the sturgeon, which is regarded as almost pure jelly, its globulous structure becomes perfectly manifest, and that if this substance be dissolved, and then reconverted into a solid, these globules again reappear, and that precisely the same phenomenon is produced by the conversion of a solution of fibrine from a fluid to a solid state. Thus it appears that albumen, gelatin, fibrin, &c. or the proximate animal principles, assume a globular form whenever they pass from the fluid to the solid state, whatever be the cause which produces that change. If the uniformity and universality of this curious fact be hereafter established, it will probably open the path to new and interesting discoveries relative to some of the most important functions of the animal economy. In the mean time it may be observed, that the view which has been exhibited of the elementary structure of the animal tissues, discloses a series of facts, which are in perfect harmony with the ordinary operations of nature. From the most simple vegetable up to the polypus, from the most simple polypus through all the ascending scale of being up to man, the characters of life are nearly the same: that the ultimate structure of the substances to which life is attached should therefore be similar, would be in perfect harmony with the great plan on which we know that all the operations of nature, with which we are acquainted, are conducted. But no consideration should induce us to acquiesce in anything as a fact, until it is fully ascertained; and it should be borne in mind that the entire series of observations relative to the globular structure of organized bodies is at present a subject of controversy, some of the most eminent authorities maintaining that they are correct, and others contending that they are fallacious.*

* See an unpublished pamphlet by Mr. R. Brown, V. P. L. S.

Of the Properties of the Primitive Tissues.

1. Each of the primitive tissues that has been described possesses peculiar and specific properties. Those which belong to the cellular tissue are wholly physical: they consist of four, namely, cohesion, flexibility, extensibility, and elasticity. Cohesion must necessarily belong to every solid substance; and it is required, in the animal tissues, because, in the performance of many of the vital functions, a considerable degree of force is exerted. The different parts of the body are continually changing their bulk, and varying their relative position: the tissues of which they are composed must therefore possess a considerable degree of flexibility, and of extensibility. Elasticity is the property which a substance possesses of returning to its original size when the cause that distends it ceases to operate. The operation of this property is of great importance and extent in the animal economy, and it is peculiar to the cellular tissue. There is reason to believe that no other texture possesses it in the slightest degree, but in so far as this substance enters as a constituent element into its composition. Although elasticity can never be the source of power; although it cannot originate motion; although it can only restore, in a contrary direction, the force which had been impressed by some other agent, yet, in the various functions of life, its action is exceedingly extensive and important. The arrangement by which this is secured is extremely beautiful. The tissue in which this property is inherent is so disposed throughout the body, that it is kept in a state of constant distension, both by its situation and by its connexions. As long as the distending cause continues to operate, the elastic property has no action; but whenever the circumstances that distend it vary, that moment its elasticity comes into play; and these circumstances vary almost every instant. Whenever the extremities of any portion of the tissue, in any part of the body, are brought nearer to one another; whenever the contents of any hollow organ are withdrawn; whenever any such hollow body is divided transversely, that instant it contracts or shrinks, and thus a power is obtained in the economy. The cartilages of the

ribs are endowed with a high degree of elasticity: the arteries possess this property in a still greater degree: it will hereafter be shown, that in the functions of respiration, and of the circulation, its use is so great, that these important actions could not possibly go on without it. The situation and action of the epiglottis afford another striking and beautiful illustration of the use to which it is applied. The windpipe, the tube which conveys air to the lungs, being placed before the œsophagus, the tube which transmits the food into the stomach, the food, in order to get into the latter organ, must necessarily pass over the former. But it is essential to the function of respiration that air should be constantly passing to the lungs: an interruption to its transmission, for any considerable time, would stop the process and destroy life; and yet the opening into the tube which is to convey the air must, necessarily, be closed every time a morsel of food or a drop of water is swallowed. How is this aperture invariably and instantly to be closed just at the moment when its closure is required, and yet to remain open at every other period? A cartilage is placed at the top of the windpipe, attached to the root of the tongue: the tongue, in the act of deglutition, necessarily passes backwards, but it cannot pass backward, without pushing the cartilage over the aperture so as completely to close it. As soon as the tongue ceases to press upon the cartilage, in consequence of the high degree of elasticity with which the latter organ is endowed, it springs up of its own accord, and so leaves the aperture open. That aperture requires to be closed only during the moment we swallow: its closure is secured by the act of deglutition; it requires to be open at every other period; it is kept open by the elasticity of its lid.

Such are the properties of the cellular tissue. As this tissue forms the basis of every organized solid, so the properties with which it is endowed are the most simple, that is, they belong to many other natural objects. Cohesion must, of course, be possessed by every solid substance. Extensibility, flexibility, elasticity, are found in vegetable, mineral, and in dead animal matter. These properties are entirely physical. They are connected with the peculiar arrangement of the particles and the chemical composition of the substances in which they reside. All the effects they produce in the animal economy are totally independent of any vital action.

2. But the second primitive tissue, the muscular, is the seat of a power properly vital. To the muscular fibre, considered as a compound of muscle and membrane, belong all the properties of cellular tissue: to pure muscle is attached only one property, which is termed contractility; and this is peculiar to it, and is truly a vital power. As it actually exists in the body, then, muscle possesses two classes of properties, physical and vital. It owes its physical properties for the most part, but especially its elasticity, to the cellular tissue with which it is combined. Cohesion, flexibility and extensibility must belong, indeed, in some degree, to its own substance; but these are of little consequence compared with its peculiar and specific property of contractility. Contractility is the property which the muscular fibre possesses of shortening itself. It is the generator of power. It is not only not a mechanical property, but it possesses nothing in the slightest degree analogous to any mechanical force. In the best contrived machinery there is no real generation of power: there is merely an application of pre-existing power to some specific object. In the reaction of an elastic body, in the recoil of a spring, there appears to be an actual production of power; but the effect thus apparently produced is the mere reaction of the force originally employed in compressing the spring. The force of the recoil can never be greater than the force employed to compress it, and the moment this power is expended, all capacity of motion is at an end. In muscular contraction, on the contrary, there is a real generation of power. If, in an animal recently killed, the interior surface of the ventricle of the heart be pricked gently with a needle, the ventricle will instantly contract with such force as to propel the needle deeply into its substance. The force of the contraction of the ventricle in this instance must be incomparably greater than the force with which it is pricked by the needle. There is, thus, an actual production of power, because the effect bears no proportion to its mechanical cause. There is, then, not only no identity, but no analogy between this power and any of the great principles of nature, which are original sources of mechanical force. And of this the complete

proof is, that its most powerful effects are produced without the intervention of any mechanical cause,—by an agent which has no relation to any physical property of matter, namely, by volition. This power, therefore, is distinct from any other in nature, and is peculiar to life. The phenomena of muscular contraction, and the laws which regulate it, will be described hereafter.

3. To the nervous tissue, besides those that are merely physical, belong two distinct and peculiar properties; and these also are vital: they are denominated the nervous and the sensorial. The nervous power consists of a property resident in the nerves, upon which the following phenomena depend:—

1. The transmission of the stimulus of volition to the voluntary muscles. 2. The transmission of impressions received from the external senses to the spinal cord and the brain. 3. The exertion of a certain action upon the blood, by which are maintained the secreting and the other assimilating processes, in which the preservation of the structure of the different organs depends. 4. The exertion of an analogous action upon the blood, by which a disengagement of caloric is produced, and the temperature necessary to animal life and health sustained. The sensorial power consists of the faculty of sensation, that is, sensation attended with consciousness or perception, of volition, and of the faculties termed intellectual. For reasons hereafter to be assigned, it is certain that the nervous and the sensorial are distinct and independent powers, and these phenomena will be further described in the proper place.

From the exposition that has been given of the properties of the primitive tissues of the body, a little reflection will show that it is possible to deduce four distinct powers to which we may refer the particular events or phenomena which, taken together, constitute, or, at least, which are invariably found, only in connexion with life. These general powers, to which distinct classes of phenomena may be referred, are—organic affinity, contractility, nervous power, and sensorial power.

1. To the first, organic affinity, are referable the phenomena of production, secretion, growth, and the various processes by which the different structures that compose the animal fabric are modelled. The power by which these effects are produced is common not only to all animal but to all vegetable bodies —it may be considered as the common property of organized beings—it appears to be the immediate result of that peculiar arrangement of parts which is termed organization: it is, therefore, appropriately termed organic, and the principle considered abstractedly may be denominated organic affinity, in contradistinction to the ordinary chemical affinities to which it is so often opposed.

2. The second general power to which vital phenomena may be referred, is contractility. With the exception of that which depends on the physical property of elasticity, it is the source of all the motion which takes place in the animal system. In all the higher animals it resides in the muscular tissue alone: in the lower, in which there appears to be no distinction of tissue, it belongs to the homogeneous substance of which the body is composed.

3. The third general power to which particular classes of phenomena may be referred is the nervous. By this power impressions are received from certain parts of the nervous system, and communicated to other parts of it; impressions are also received from the external world, and conveyed to particular parts of the same system; it is, therefore, by this power that the animal is connected with the external world; and it also exerts, as has been shown, a very important influence over certain actions which are indispensable to animal existence.

4. The fourth general power, the sensorial, is that to which we must refer the important faculties already enumerated, namely, perception, volition, and those which are termed intellectual. By these faculties the animal is capable of enjoyment: they do not so much constitute his being—they do not so much contribute to the maintenance of existence, although existence can be prolonged only a few moments after their operation has ceased, as to the rendering existence a good. They are the final cause for which all the other faculties exist, because they are the ultimate end for which the animal itself lives. Thus, the nervous and the muscular powers are those by which the life of the animal is preserved, and by which it affects and is affected by the external world: the sensorial are the powers by which the ultimate end of its being is attained: it follows that the final cause of the nervous and the muscular is the

maintenance of the sensorial powers: accordingly, it is established by direct experiments which we shall detail hereafter, that the muscular is uniformly obedient to the nervous, and the nervous to the sensorial power, while the sensorial power itself is subordinate to the final cause of animal existence—enjoyment.

In the construction of the animal frame, the tissues which have been described are variously combined and modified. Some are disposed in a definite order, and moulded into a peculiar form: others are disposed in another order, and moulded into a different form. These definite arrangements constitute organization. Each determinate organization, when moulded into a given form, constitutes what is called an organ. The figure, the magnitude, and the general aspect of the different organs are infinitely various. Their physical properties depend upon the tissues of which they are composed, and upon the modifications which those tissues undergo. Their chemical properties depend upon those of the tissues, and of the fluids. Their vital properties are peculiar and specific. Every individual organ is endowed with the power of performing a specific action: the performance of that action is the sole object and end of its existence, and that action, whatever it be, is termed its function. Thus every organ is an instrument, and as life consists in a series of actions, performed by different organs, the latter are termed, as has been stated, the instruments of life. And that this organic power is connected with organization, is inferred from the fact, that the effects produced by different organs invariably correspond with the particular arrangement of their elementary tissues, that is, with their peculiar organization. The stomach never possesses the power of secreting bile: the liver never secretes the gastric fluid: the peculiar organization of a part is essential to, and secures its peculiar action.

Thus it appears that every individual organ is the seat of some special function. A function consists of certain phenomena, which have a peculiar relation to each other, and which concur in the production of a definite object. These phenomena occur in a series: the succession of each phenomenon in the series is definite and fixed. Thus, the function of respiration consists, first, of the motion of the muscles, which raise the ribs and depress the diaphragm; secondly, of an increase in the cavity of the cells of the lungs; thirdly, of an ingress of atmospherical air into those cells; fourthly, of certain changes produced in the quality of the blood during its passage through the lungs, and so on. In this instance each phenomenon follows in a certain order, and the whole concur in the production of a definite object; and the same is true of every function of every living being.

Since life consists in a series of actions performed by different organs, it is obvious that the main object of physiology must be to give an account of these actions or functions. In order to execute this task with advantage, it is necessary to adopt some classification of the functions, and a simple and natural arrangement is very important. On examining carefully the circle of actions performed by the living being, we observe that these actions have for their object the preservation of the individual, the reproduction of the species, and the bringing the individual into communication with other beings. The first class of functions comprehend those of nutrition; the second, those of reproduction, and the third those of relation. The function of nutrition consists of the following processes:—digestion, circulation, respiration, secretion, absorption, and excretion. The function of reproduction comprehends the different processes of generation. The function of relation comprehends locomotion—the nervous influence; sensation, the particular senses and the intellectual faculties; voice, speech, and so on. Of these functions we shall treat pretty much in the order enumerated, beginning with the process of digestion, and describing the blood, which it is the great object of this process to form.

Of Digestion.

We have seen that one of the essential characters of a living being is the power it possesses of resisting within a certain range the ordinary influence of physical agents, and of maintaining its integrity under circumstances in which it would be decomposed were it destitute of a vital principle. These vital phenomena are effected by the establishment of a circle of actions in the interior of the living body, by which its integrant

particles are maintained in a state of alternate decay and renovation; its old particles being continually removed, and new particles being deposited in their place. The activity with which this interchange is carried on varies in every different individual, and in the same individual at different periods of its life; but the rapidity with which certain processes are accomplished would seem to show that that interchange cannot be slow. Hales ascertained by direct experiment, that a sunflower, weighing three pounds, exhaled twenty-two ounces in the space of twenty-four hours, that is, nearly half its weight: and by a series of experiments, Reil ascertained that, in his own person, he lost by the process of perspiration thirty-one ounces in twenty-four hours. Attempts have been made to calculate the space of time in which every particle existing in the human body at any given period would be removed and replaced by new matter, and a notion has prevailed that a complete and entire change is effected in the course of seven years: but this is mere conjecture.

From the continual removal of the old, and the corresponding deposition of new particles, a source must be provided for furnishing the body with a supply of fresh materials. That source is the aliment: but the aliment as it is received by the living body is always a compound, often an exceedingly heterogeneous substance; while it is an ascertained law that no food can contribute to the support of the body unless it be decomposed and resolved into its primitive elements. In order to accomplish this resolution of the alimentary matter, a certain process is established, in some cases simple, in others extremely complicated. The process itself is termed, in the vegetable, nutrition; in the animal, digestion; and the organs by which it is accomplished, constitute, in the former, the nutritive; and, in the latter, the digestive, apparatus. There is an invariable relation between the simplicity or complexity of the apparatus and the simplicity or complexity of the process; and also between the complexity of the process and the elevation of the individual in the scale of being.

The simplest case of nutrition is found, where the physiologist might have expected to find it, in the most simply constructed vegetable. In plants, in general, indeed, this process is much more simple than it is in the animal, and it would seem to be one office of this great division of organic being to perform the transformation of dead matter into living substance. For it is the part of the plant to act upon inorganic matter: to derive its nourishment from earths, salts, airs, compound substances which it decomposes, and the elements of which recombining anew, it assimilates into its own proper nature. On the contrary, the animal in general operates either upon vegetable or animal substance. The elements of the mineral kingdom would seem to be too remote from the nature of the animal, to be capable of being converted into its substance, unless previously elaborated by the vegetable. By its nutritive organs the plant acts upon and assimilates inorganic matter: by its digestive organs the animal acts upon and assimilates organic matter already organized by the vegetable. Hence plants may be considered as the great laboratory in which Nature prepares food for animals, and thus exhibits a mutual relation and dependence between the mineral, the vegetable, and the animal kingdoms, truly harmonious and beautiful. Still, however, this representation must be considered only as generally, and by no means as universally true: for plants are not nourished exclusively from mineral substances, nor are animals nourished exclusively from vegetable matter.

It has just been stated that the simplest case of nutrition is found in the most simply constructed plant. Such, for example, are the fuci, many tribes of which without any root, without any special organ of any kind, derive their nourishment from air and moisture alone. A very elegant example of this extreme simplicity of structure and function is afforded by the aërial epidendrum, a beautiful plant, a native of Java, and of the East Indies, beyond the Ganges. In the latter region it is stated to be not uncommon for the inhabitants to pluck it up on account of the elegance of its leaves, the beauty of its flower, and the exquisite odour it diffuses, and to suspend it by a silken cord from the ceilings of their rooms, where, from year to year, it continues to put forth new leaves, new blossoms, and new fragrance, excited to new life and action only by the stimulus of the surrounding atmosphere. Similar examples are furnished by some of the most succulent plants of the hot cli-

mates, which, though they are indeed provided with a root, yet, according to the opinion of the ablest physiologists, this organ is not to them an instrument of nutrition: on the contrary, it is conceived that these plants thrust their root into the earth merely for the purpose of supporting themselves in an erect position, because they are capable of growing only in soils or sands so extremely arid, that no moisture can possibly be extracted from them; and they quickly perish if they are exposed to wet, or to a rainy season. In all these cases nutrition is effected by the common substance of which the plant is composed, and the materials from which it is derived are air and the moisture suspended in it. Such plants may be considered as placed on the very confines of organized existence, and as transmuting in the simplest possible manner inorganic matter into living substance.

The first advancement from this, the lowest point of organization, is found in the more perfect plants. In all these the organ of nutrition is the root. Every other part of such plants may be destroyed, but if the root remain uninjured the plant will regerminate; while, if the root perish, the plant is irrecoverably lost. Such plants require for their sustenance other substances besides air and moisture: their nutrient matter being of a more heterogeneous nature, demands a more complicated apparatus for producing the necessary changes. The root forms that apparatus, and is thus a special organ, provided for the purpose of nutrition; and, in a physiological point of view, may be considered as the first advancement in complication of structure, and in corresponding complication of function.

In the organization of the simplest animals there is no appreciable advancement in structure, although they unquestionably perform additional functions. The very lowest animal probably enjoys some degree of sensation, and there can be no question that it possesses the power of spontaneous motion. Yet it appears to perform the function of nutrition in a manner perfectly analogous to that of the simplest plant. In studying the organization of living creatures, we observe, without doubt, traces of a graduated scale of being: but either the graduation of the scale is not perfect, or we are ignorant of many of the degrees that must be marked upon it; either the chain is defective, or some of its links are unknown to us. Thus the creatures placed at the bottom of the animal scale seem to possess even a less complicated structure than the perfect plant. These simple beings form the curious class of animated creatures termed the *infusoria*. When dead vegetable or animal matter has been kept for some time in a state of maceration in water, in a moderately warm temperature, the fluid is found to swarm with living creatures. Because these beings appear to be produced by the infusion in water of vegetable or animal substances, they have received the name of *infusoria*. Their extreme minuteness places them beyond the cognizance of unassisted sense, and we owe our knowledge even of their existence to the microscope. Of these creatures, the minutest and the simplest is a transparent globule, having the form of a point (*fig.* 13), which, because it is conceived to be placed at the ultimate limit of animal existence, is called by Muller the *monas termo*. All naturalists are agreed that this minute point is an organized being of an animal nature. The inference that it is an animal is founded on its motion, which has all the appearance of being spontaneous, and which, in the actual state of our knowledge, certainly cannot be referred to any external physical cause, or to any chemical agency. It seems scarcely possible to contemplate its movements for any considerable time without being satisfied that it is truly spontaneous. All who have made a particular study of minute animals have considered it as belonging to this class of beings; and Cuvier has placed it at the bottom of his Animal Kingdom, or at the commencement of the animal scale. It is found not only in infusions of vegetable and animal matter, artificially prepared, but, when the temperature is mild, in stagnant waters, whether salt or fresh. It seems to be a vesicle, or to consist of a delicate membrane inclosing a transparent fluid: hence it is described by Professor Carus as a living animal cellule. If it be difficult, on account of its extreme minuteness, to ascertain its structure with exactness, it is quite certain that animalculi of precisely the same figure and appearance, but of a larger size, and which seem to consist of a congeries of these minuter beings, are vesicular. In these larger creatures, the membrane forming

Fig. 13.

the external envelop of their body can be distinguished from the fluid contained within, and in that fluid can be perceived numerous globules of a smaller size, apparently vesicular also. This is extremely well seen in the *Volvox Globator* (*fig.* 14).

Fig. 14.

Now in this, the lowest class of animals, the function of nutrition is performed in the simplest manner, and is perfectly analogous to that in the vegetable. Their nutritive matter is received by imbibition through the parietes of their external membrane, without any mouth, and without any apparatus for digestion that can be distinguished.

The first advancement from this simple condition of animal existence is observed in a higher tribe of animalculi, and also in the lowest order of polypes. It consists of a membranous sac open at one extremity (*fig.* 15). The figure of the

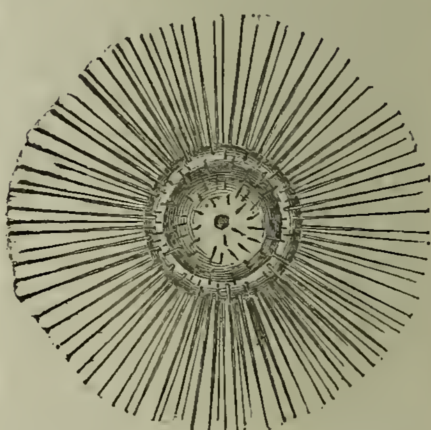
Fig. 15.

animalcule is that of a purse, which has given name to the tribe denominated *Bursariæ* (*fig.* 15.) The figure of the polype is very similar to that of the flower termed Campanula, and it is therefore called bell-shaped. The inhabitants of coralline and sponge are constructed essentially in this manner. Instead of a membrane inclosing a cavity without any aperture, they consist of a membranous cavity open at one extremity. This conformation affords the first and the simplest conceivable rudiment of an alimentary canal: the whole internal surface of the animal must be considered as forming one extended stomach, and hence the animal has been described by Cuvier, as being a sentient self-moving sac capable of digesting food. In the higher tribes of this order, processes or lashes are arranged around the external margin of this aperture (*figs.* 16, 17, 18), which are

Fig. 16.

Fig. 17.

Fig. 18.



This figure represents the mouth of one of these creatures, very highly magnified.

endowed with the power of motion, and by means of which the fluid in which the animal swims, and which contains its aliment, is propelled into its rudimentary digestive canal. In the tribes placed above these, the aperture leading to this internal cavity is not always open, but is capable of alternate contraction and expansion, thus exhibiting the first and the most simple form of a mouth.

It has been stated, that in the more perfect plants the root is the organ by which the function of nutrition is performed, and that if the root be injured, the plant inevitably perishes. Yet there are species of plants in which the trunk can be made to perform the office of the root, and the root that of the trunk. In the prunus and salix, the cherry and

willow tribes, if the stem branches be bent down to the earth, plunged into it, and continued in this situation for a few months, these branches will generate radicles, which will perform the proper functions of the root. If, subsequently, the original root be dug up and suffered to ascend into the air, so that the whole plant shall become completely inverted, the original root will throw forth stem branches, and will bear the wild fruit peculiar to its tribe. The rhizophora *mangle*, or mangrove tree, grows naturally in this manner; for its stem branches, having reached a certain perpendicular height, bend downwards of their own accord, and throw forth root-branches into the soil, from which new trunks arise, so that it is not uncommon, in some parts of Asia and Africa, to meet with a single tree of this species covering the oozy waters in which it grows with a forest of half a mile in length. The ficus *Indica*, or banyan, grows in the same manner, and often with enormous trunks, equally derived from a primary root. Precisely analogous is the curious property possessed by the *Bursariæ* and the *Polypi*. If these animals be inverted or turned completely inside out, that surface which was naturally external performs the office of the internal perfectly, and the process of nutrition is carried on without the slightest apparent inconvenience or change. As we ascend in the scale of being, however, these vicarious offices cease to be performed: a specific organ is provided for every particular function: the function can be executed only by its own proper organ, and if the organ be destroyed or injured the animal perishes.

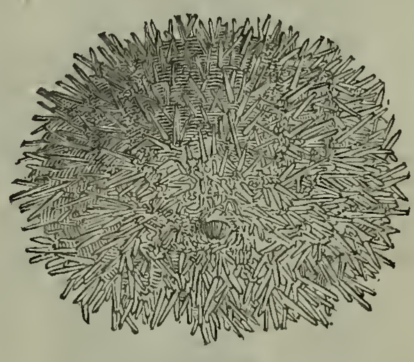
Tracing, in the ascending scale, the successive advancement of structure in these simple beings, after an animal possessing an internal cavity, either with the aperture always open, or with the power of contracting or expanding the mouth of the opening, we next come to a complication which is exceedingly important. It consists of a distinct membranous tube included in an external envelop, the external envelop forming what may be properly termed a body, and the internal tube affording the first rudiment of a stomach, or rather the first indication of a special digestive organ. The animals termed *vorticellæ* are constructed in this manner, and it has been lately conceived that the vibrio of paste possesses an analogous structure (*fig.* 19). In the next order of zoophytes we meet with a mouth which is very distinctly formed, and which in most cases is surrounded with numerous tentaculi. The mouth opens into a

Fig. 19

shut sac or stomach, which is perfectly distinct from the mass of the body. The stomach rejects its excrementitious matter by the same passage that admits its aliment, so that one common aperture serves both for mouth and anus. In the *medusa* all these points are well seen. On the inferior surface of the body there is a simple aperture, or mouth, for the purpose of suction. Its cavity leads by four apertures into a like number of sacs or stomachs excavated in the gelatinous substance of the body. And these stomachs, in a manner almost inconceivable, are capable of digesting hard substances, and especially the small prickly fishes upon which they prey.

In the *echinodermata*, the highest order of zoophytes, there is a further and a very important advancement in organization. In the asterias, or star-fish, the stomach is not only quite distinct from the general mass of the body, but the entrance to it is surrounded by teeth, which are generally five in number (*fig.* 20). These animals afford the

Fig. 20.

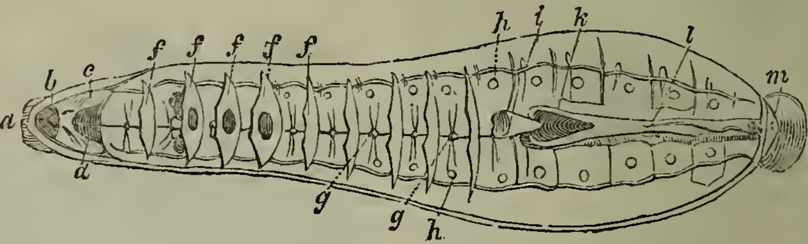


first trace of distinct organs of mastication. With these teeth they seize upon small fish and other minute animals, on which they prey; for these, and almost all the lower orders of creatures, live upon animal matter. In the echinus, or sea-hedgehog, the organs of mastication are still more developed.

Ascending considerably in the scale,

we come to the *articulata*, in which the organs of digestion are very much more perfect. As an example of the structure of this class, we may take the leech, an animal familiar to every one. The mouth of the leech is of a triangular figure. It is furnished with little sharp edges for the purpose of dividing the skin (*fig*. 21.) Attached to the mouth is a strong fleshy pharynx, which is the

Fig. 21.

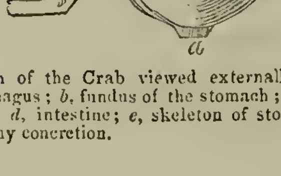


Longitudinal section of a Leech; *a*, sucking surface of the mouth; *b*, cavity of the mouth opened, with a view of its triangular aperture; *c*, muscles of the pharynx; *d*, cavity of the pharynx: *f*, perforated septum of the stomach; *g*, chain of ganglia; *h*, respiratory vesicles; *i*, lateral vessel; *k*, pylorus; *l*, commencement of the intestine; *m*, anus.

principal agent in sucking blood. Next to this follows a long and capacious stomach, consisting of a membranous bag, divided by several septa into large cells, which communicate with each other by oval apertures. Somewhat more than midway down the body, the intestine arises from this extended stomach: it commences by a small funnel-shaped valvular opening, and terminates in a minute anus placed at the superior edge of the posterior disc. But though provided with an anus, it more frequently discharges its excrementitious matter from the mouth than through its narrow intestine, and thus it forms a kind of link between the inferior and the higher stages of organization.

We shall advert to but one order more in the ascending scale—the *crustacea*. In this order, as in the crab, the lobster, the prawn, we find, for the first time, the organs of mastication fully and completely formed; we have jaws, properly so called (*fig*. 22, 23). Nor should we overlook the singular stomach with which they are provided: few things in animal structure are more curious: it is formed on a bony apparatus, to certain parts of

Fig. 22.



Stomach of the Crab viewed externally; *a*, œsophagus; *b*, fundus of the stomach; *c*, pylorus; *d*, intestine; *e*, skeleton of stomach; *f*, stony concretion.

Fig. 23.

The same opened from the œsophagus length-ways, and at the lower part; *a*, great central teeth of the stomach; *b*, *b*, two large lateral teeth; *c*, *c*, two small lateral teeth; *d*, bony lamina on the anterior and larger or cardiac portion of the stomach; *e*, the smaller or pyloric portion of the stomach; *f*, entrance to the intestine.

which around the pylorus the teeth are affixed, which are moved by distinct muscles, and so arranged that nothing can pass the pylorus without being completely comminuted.

Brief and imperfect as the preceding sketch must appear, yet it may suffice to convey to the reader a general idea of the progressive advancement which may be traced in the structure of the digestive organs from the lowest to the more perfectly organized animal. And, in fact, at the point at which we have now arrived, we recognize every essential part of the digestive apparatus, which is to be found in the highest animal. We have organs for apprehension, for mastication, for deglutition, for digestion, for excretion: we have a mouth, teeth, jaws, a pharynx, a stomach and intestines. In a physiological view, therefore, more especially considering the brevity which must be observed in

this treatise, it is unnecessary to trace the complication further.

In all the higher animals the function of digestion consists of four distinct acts, namely, mastication, deglutition, chymification, and chylification; to which must be added the process of excretion. We shall first of all describe, very briefly, the apparatus by which these actions are performed; and, secondly, consider the actions themselves.

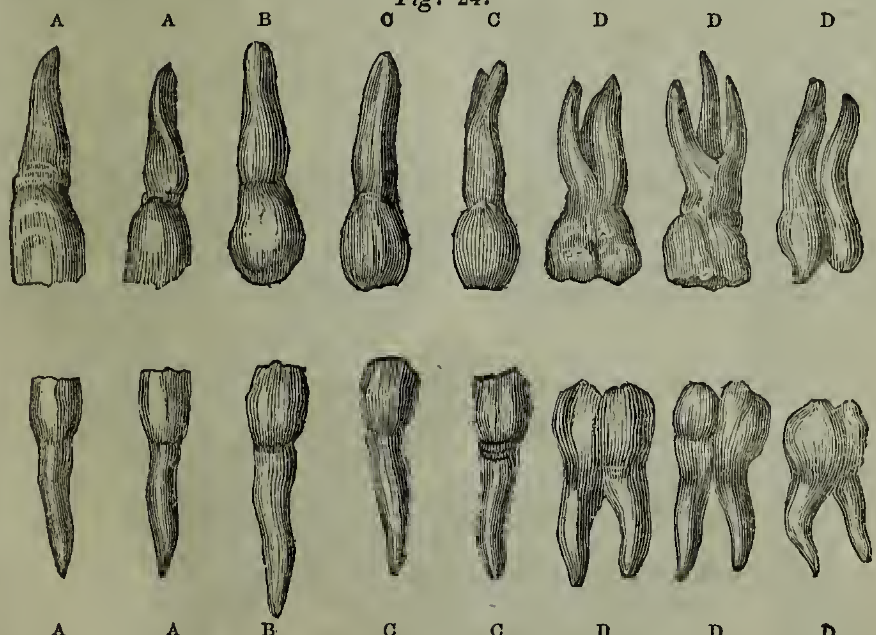
1.—*Of the Organs of Mastication.*

Mastication is essential to digestion. Its object is minutely to divide the food. In all animals furnished with distinct digestive organs, expedients are provided for accomplishing this purpose. These expedients are varied according to the kind of food on which the animal subsists, and according to the general organization of the body. They consist, for the most part, of a mouth, of teeth, of jaws furnished with powerful muscles to act upon them, of the tongue, and of the salivary glands.

The mouth, consisting principally of the lips, and, in the view we are now taking of the organ, of the cheeks also, is formed of numerous muscles which are capable of the utmost complexity and diversity of action. The form and situation of the teeth, as well as of the jaws which contain them, are extremely varied; and so strictly are these diversities connected with the peculiar habits of the animal, with the species of alimentary matter on which it lives, and with the general organization of its body, that naturalists assume these organs as affording the most clear and certain characters on which to found the basis of their systematic classifications.

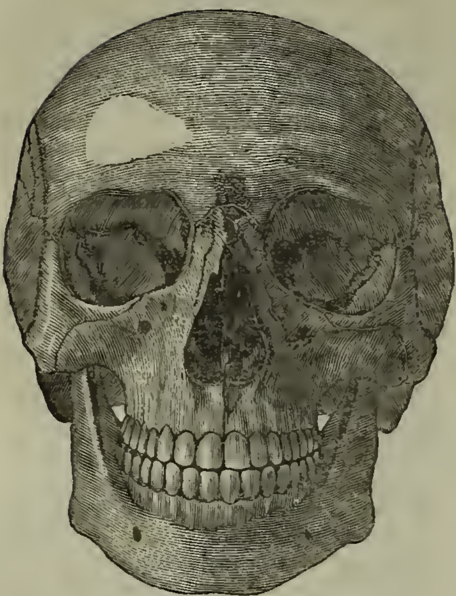
Some animals live entirely on vegetable, others wholly on animal matter, and to the health and vigour of others a mixture of both is necessary. These differences in the habits of animals require a corresponding modification of the organs of mastication, and especially of the teeth and jaws. The differences observable in the configuration of the teeth have led anatomists to divide them into separate classes. Those situated in the front of the jaw are called incisores, or cutting teeth (*fig*. 24): these bodies are wedge-shaped (A A). Placed at the sides of the incisores are the cuspidati or the canine teeth (B B): the bodies of these, also, are in the shape of wedges. Immediately behind the cuspidati are the bicuspidati, or the first and second grinders (C C); and the largest of the teeth, placed the most posteriorly, are called the molares, or the grinders (D D). In every different

Fig. 24.



Upper and lower teeth of the left side of the jaw; A, A, A, A, the incisores; B, B, the cuspidati or canine teeth; C, C, C, C, the bicuspidati, or first and second grinders; D, D, D, D, D, D, the molares, or grinders.

Fig. 25.



Front view of the Skull, with the teeth in their natural situations.

Fig. 26.

Skull of the Cow.

class of animals these teeth vary in strict accordance with the diversity of food on which they subsist. Thus in the graminivorous quadruped the molares are large and broad. Their magnitude, indeed, is so great as absolutely to require that the jaw should be much elongated, in order to make room for them (*fig.* 26). The condyles of the lower jaw (*a*), or those extremities by which the lower is united with the upper jaw, are rounded, in order that the lower may move upon the upper jaw with the utmost freedom in every direction, but especially laterally. This lateral motion is indispensable to the action called grinding, an action peculiarly adapted for the comminution of the substances upon which these animals feed. It is worthy of remark, that in the horse, which crops the herbage by snapping it crosswise, there is this further modification of the teeth, that the incisores have broad cutting edges, which meet like the blades of pincers, the precise conformation needed.

The structure of the teeth, and the general figure of the jaw in carnivorous quadrupeds, presents a striking contrast (*fig.* 27). In this class the molares are comparatively small (*fig.* 24), at the same time they are much more pointed. On the other hand the cuspidati are remarkably large (*fig.* 24), and the incisores in general are quite pointed (*fig.* 24). The jaws themselves

Fig. 27

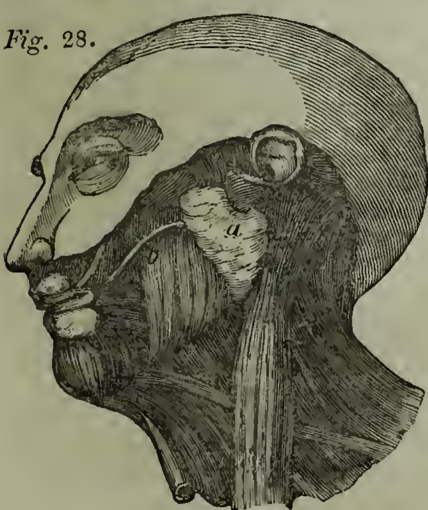
Skull of the North Polar Bear.

are short (*fig.* 27, *a*). Their condyles are so locked in by the fore and back parts of their articular cavities, that any degree of lateral or rotatory motion is prevented (*fig.* 27, *b*); the jaw can move only in a vertical direction, or is capable only of elevation and depression. All this arrangement, it is obvious, is adapted for lacerating and cutting the animal fibre. Living entirely upon flesh, these animals do not need a grinding motion of the jaw, but they require a powerful cutting instrument: hence their small and sharp molares; their large cuspidati; their pointed incisores, and the prodigious power of the muscles by which the teeth of their lower are closed upon those of their upper jaw. The most superficial examination of the human teeth shows that they hold a middle place between those of herbivorous and carnivorous animals. (*fig.* 25).

The tongue is a very important organ both of mastication and of deglutition; it consists almost entirely of muscular substance, covered by mucous membrane. Its fibres are variously arranged, and are very intimately connected together, so as to render it capable of motion in every conceivable direction, a structure admirably adapted for conveying the food wherever it may be necessary to be acted upon by the teeth.

Among the organs which are essential to the process of mastication, must be reckoned the salivary glands (*fig.* 28).

Fig. 28.



a, Parotid gland; *b*, duct for conveying the saliva into the mouth.

These bodies convey to the mouth the saliva they secrete, by numerous ducts which open into it. In man the chief salivary glands are three on each side (*fig.* 28); the parotid, situated on the cheek; the submaxillary, situated beneath the lower jaw; and the sublingual, situated beneath the anterior portion of the tongue. These glands pour into the mouth a large quantity of fluid; it is estimated that they afford about eight ounces of fluid, which is mixed with the food at each meal.

2.—*Of the Organs of Deglutition.*

The organs of deglutition are the tongue, the pharynx, and the œsophagus. The tongue has been already described; its posterior portion or base is connected, through the medium of the arches of the palate, with the organ termed the pharynx. The pharynx, so called from its conveying food to the stomach, and air to the lungs, is a large muscular bag, having the form of an irregular funnel, the large opening of the funnel looking towards the mouth, while the under and smaller end of it constitutes the tube which leads to the stomach, termed the œsophagus. The muscles which compose the pharynx, and with which it is connected, are capable of raising or elevating it, that is, of bringing it nearer the base of the tongue; of depressing it or carrying it from the base of the tongue, and of causing it to contract upon itself, that is, of narrowing its calibre.

The œsophagus, called also the gullet, derives its name from its office of conducting the food into the stomach. It is a fleshy tube which begins from the inferior part of the pharynx (*fig.* 29), descends along the neck, passes through the thorax, and terminates in the stomach (*fig.* 30). It consists of three coats or three membranous coverings, which are perfectly distinct from each other: the first is composed principally of cellular substance; the second of muscular fibre; and the third of mucous membrane. The second or mus-

Fig. 29.

Œsophagus: *a*, *b*, section, showing the interior circular fibres; *c*, the external longitudinal fibres.

cular coat consists of two layers of fibres; all the fibres which form the external layer have a longitudinal direction; all those which form the internal layer are circular. The function performed by this tube requires that it should possess two kinds of motion, that of shortening itself, and of lessening its diameter. It is obvious that the contraction of its longitudinal fibres will shorten it, and that a contraction of its circular fibres will narrow it. The inner or mucous coat is continued from the lining of the mouth; it is formed into numerous longitudinal folds, which expand so as to become scarcely visible when the œsophagus is dilated, and it is always abundantly lubricated with a mucous fluid.

3.—*Of the Organ of Chymification.*

The process termed chymification is performed by the stomach. The stomach is a large membranous bag situated obliquely across the upper part of the abdomen (*fig.* 30). Its figure has been

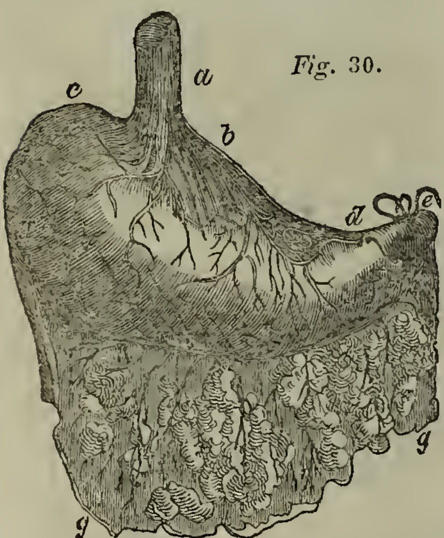


Fig. 30.

The Stomach: *a*, œsophagus; *b*, cardiac portion; *c*, great or left extremity; *d*, small extremity; *e*, stomach tied at the pylorus; *f*, great anterior curvature; *g*, omentum.

not unaptly compared to that of the bag of a bag-pipe. It is capable of holding in the adult man, when moderately distended, about three pints. It has two extremities (*fig.* 30, *c*, *d*), two curvatures (*fig.* 30, *f*, *b*, *d*), two orifices (*fig.* 30, *a*, *e*), and three coats.

The large extremity is situated on the left side of the body (*fig.* 30, *e*), the stomach gradually diminishes in bulk towards the small extremity which is situated on the right side. The inferior border of the stomach, which is convex, is termed the great curvature, or arch (*fig.* 30, *f*); the superior border, which is also convex, is named the lesser curvature, or arch (*fig.* 30, *b*, *d*). The two orifices or openings of the stomach, are situated in the lesser arch (*fig.* 30, *a*, *e*). The left (*fig.* 30, *a*) is formed by the termination of the œsophagus, and is therefore termed the œsophageal opening, or the cardiac orifice; the right (*fig.* 30, *e*) is formed by the termination of the small extremity, and is denominated the pyloric orifice. It is about three inches lower than the œsophageal, and is therefore sometimes termed the inferior orifice.

The structure of the stomach is similar to that of the œsophagus. It possesses three coats, of which the external derived from the lining membrane of the abdomen, termed the peritoneum, is denominated the peritoneal coat. The second coat is composed of muscular fibres, hence it is termed the muscular coat. The fibres consist of two planes, which, like those of the œsophagus, are arranged in different directions. The external plane is longitudinal; it is in fact a continuation of the longitudinal fibres of the œsophagus; it extends from the great to the small extremity, and upon each side of the lesser curvature forms a thick strong muscular band. The second plane is circular; it forms a layer considerably thicker and stronger than the other. It is obvious that the effect of the contraction of the first plane will be to shorten the stomach, or to diminish its length from extremity to extremity; that the effect of the contraction of the second plane will be to narrow its cavity, or to diminish its capacity; and that the result of these alternate or combined actions upon the contents of the organ will be to agitate them gently, to move them in various directions; and since the pyloric orifice is three inches lower than the œsophageal, to direct them ultimately towards the pylorus.

The pylorus consists of a ring of muscular fibres covered with mucous membrane. It is placed, as has been stated, at the lesser extremity of the stomach (*fig.* 30, *e*). This ring of

fibres form what anatomists term a sphincter, and it is called the Sphincter Pylori (*fig.* 39, C, and *fig.* 40). It completely closes the aperture; and this was necessary, in order that the contents of the stomach might not escape before they had been duly acted upon by the organ: at the same time, however, it was necessary that the orifice should open as soon as the function should be completed. It was requisite, therefore, to construct a valve which should close the aperture as long as was necessary, and which should open of its own accord the moment this contrary action was required. This power of contracting on the application of specific stimuli is one of the most wonderful endowments of living substance: it is a property peculiar to the muscular fibre, and will be fully explained when we treat of muscular action. At present our only object is to point out the admirable use which is made of this property in this particular instance.

The third or inner coat of the stomach is also termed the mucous; it is continued from the inner coat of the œsophagus; but it has more of a velvet appearance, and is more extensive, being folded into numerous doublings, which are termed rugæ (*fig.* 31). It is this

Fig. 31.

A portion of the inner surface of the stomach, shewing the folds formed by the mucous coat, and the velvety appearance it assumes.

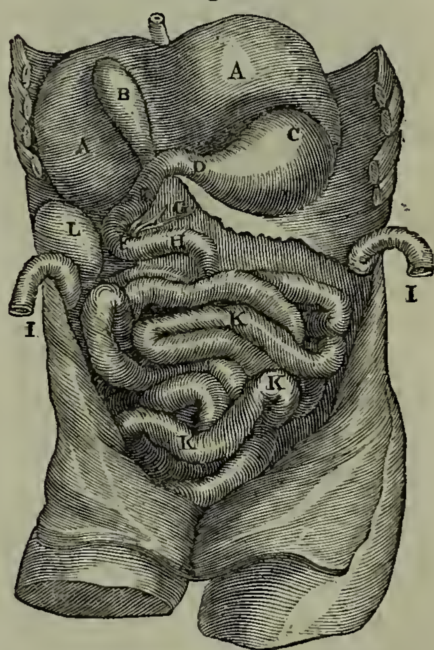
membrane which is more immediately connected with those secretions of the organ by which it performs the most important part of its function.

These different coats of the stomach are connected together by exceedingly delicate cellular tissue. Its blood-vessels and nerves are more abundant than those of any other organ of the body: its nerves especially are remarkable, not only for their number, but also for the variety of the sources whence they are derived. Accordingly, of all the organs of the body, the stomach is the most exquisitely sensitive; it partakes, in a most remarkable manner, of all the general actions of the system; it sympathizes with all the changes in its individual organs; it may be regarded as a kind of common centre, by which all the organic functions are connected together and their motions regulated. For this reason Mr. Hunter called it the centre of sympathies. This adjustment will appear the more beautiful when the extent of the system of the organs and functions concerned in nutrition, and the necessity of providing some means by which their various actions may be connected and combined, are considered.

4.—*Of the Organs of Chylification.*

The organs of chylification consist of the small intestines, (*fig.* 32,) the pancreas, (*fig.*35) and the liver (*fig.*32, A A). The small intestines are directly concerned in

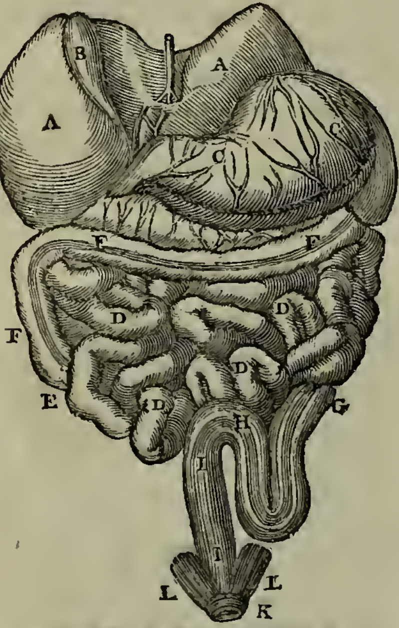
Fig. 32.



A, A, the liver raised to shew its under surface; B, the gall-bladder; C, the stomach; D, the situation of the pylorus, and beginning of the duodenum; E, the duodenum making a turn to go across the spine; F, the termination of the ductus communis choledochus in the duodenum; G, the pancreatic duct, terminating in the duodenum at the side of the common biliary duct; H, the continuation of the duodenum; I, I, the cut ends of the great arch of the colon turned aside; K, K, the convolutions of the jejunum and ileum; L, the right kidney.

the process; the pancreas and the liver are only contributary to it. The intestines taken together consist of a long cylindrical canal, which begins at the pyloric orifice of the stomach, and terminates in the anus (*fig.* 33). They are always capacious and long in proportion as the food to be digested is more or less analogous to the substance of the animal it is intended to nourish. In the human adult they are about six times the length of the body: in children, on account of their smaller stature, they are about ten times the length of the body. The intestines are divided into small and large. *fig.* 33). The small intestines, the

Fig. 33.



A, A, the liver; B, the gall-bladder; C, C, the stomach; D, D, D, D, the small intestines; E, commencement of large intestines in intestricum cæcum; F, F, F, the colon; G, H, sigmoid flexure of colon; I, I, rectum; K, anus surrounded by the sphincter ani; L, L, two muscles attached to the anus, termed the levatores ani.

only part of the tube concerned in the process of chylification, are perfectly analogous in structure to the stomach, (*fig.* 48) possessing the same number of coats, which are arranged in the same manner, excepting that the internal or mucous coat is plaited into numerous transverse folds termed *valvulæ conniventes*, (*fig.* 34), the object of which is to extend the surface of the membrane, in order to afford a greater space for the absorbing mouths of the lacteal vessels, and at the same time to perform, in some degree, the function of valves, to retard the motion of the chyle, in order that it may be more readily and completely absorbed.

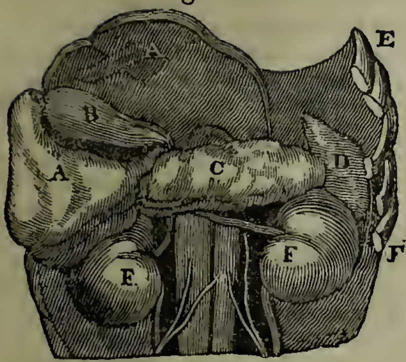
Fig. 34.

The small intestines are divided into the *duodenum* (*fig.* 32, D, E, H), the *jejunum* and the *ileum* (*fig.* 32, K K). The duodenum is so large as to have received the name of a secondary stomach: it is more firmly fixed to the body than the other intestines; it does not, like them, float loosely in the abdomen; its muscular coat is thicker; its mucous coat presents irregular rugæ in place of valvulæ conniventes. At the distance of about three or four fingers breadth from the pylorus, it is perforated by the termination of the pancreatic and the biliary ducts (*fig.* 32, F G; 49, F), which pour into it the pancreatic juice and the bile. Innumerable mouths of lacteal vessels, hereafter to be described, begin to appear in this organ, for the purpose of absorbing the chyle; it is here especially that the chyle is formed: the chief use of the jejunum and ileum appears to be to afford space for the distribution of the open mouths of the lacteal vessels by which it is absorbed: hence in these intestines the valvulæ conniventes are large, the villi prominent, and the lacteal vessels much more numerous and manifest.

The pancreas is a salivary gland situated in the upper and back part of the abdomen, between the spinal column and the stomach (*fig.* 35, C). Its office is to secrete a peculiar fluid very analogous to saliva, which it pours into the duodenum by a distinct duct (*fig.* 49, E E,) at the point already indicated (*fig.* 32, G).

The liver, the largest gland in the body, in like manner secretes a peculiar

Fig. 35.



A, A, the under surface of the liver turned upwards, and to the right side: B, the gall-bladder; C, the pancreas; D, the spleen; E, E, the ribs; F, F, the kidneys.

fluid, termed the bile, which it pours into the duodenum by a distinct duct, called the *ductus communis choledochus* (*fig.* 49, C, F,) at the same point as that at which the duct of the pancreas penetrates it (*fig.* 49, F).

5.—*Of the Organs of Excretion.*

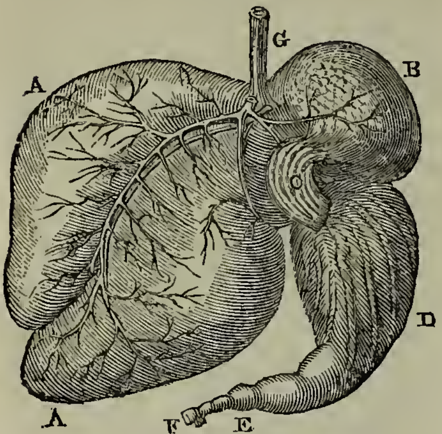
The organs of excretion are the large intestines. (*fig.* 33, E, F F F, G, H, I.) They are divided into cœcum (*fig.* 33, G), colon (*fig.* 33, F F F), and rectum (*fig.* 33, I I). They have the same general structure as the small. They are divided from the latter by a valve, termed the valve of the colon, which allows a free passage for the contents of the small into the large intestines, but completely prevents their return. This valve is formed by the mucous membrane of the intestine; and the valvular apparatus thus placed at the commencement of the large intestines, points out distinctly that the function performed by these two parts of the canal is essentially different, and indicates with precision the very point where the function of the small intestines ceases and that of the large commences. Without doubt, the great physiological difference between these two portions of the alimentary canal is that the small intestines constitute the organs in which the chyle is formed and absorbed; while the large intestines constitute the organs by which the refuse matter is carried out of the system. Few or no lacteal vessels are found in their entire tract; and in a state of health they are not observed to contain chyle. They are, however, furnished with a considerable number of lymphatic vessels which probably absorb the more fluid parts of the fæces, so that nothing that can ultimately contribute to nutrition may be lost. The chief peculiarities of their structure appear to be intended to render the progress of their contents slow; to retain them a considerable time; and, at last, to allow them to be evacuated only at certain intervals, a disposition which a moment's consideration will show to be absolutely essential to the comfort of the animal.

Of the Digestive Apparatus in the Herbivorous Quadruped.

Such are the structure and arrangement of the digestive apparatus in man, and in the animals which most nearly resemble him. In certain animals which live upon particular kinds of food, a part of this apparatus is modified in a very remarkable manner. This is especially the case with the herbivorous quadruped. The modification of the organs of mastication in this class has already been spoken of. The adaptation of the structure and disposition of its stomach and intestines to the food on which it subsists, is equally striking and curious. Living solely upon grass, which contains only a small proportion of nourishment in a large bulk, and which at the same time requires a great deal of mastication, these animals would be absolutely incapable of procuring sufficient nutrient matter, and of preparing it properly for the action of the stomach, without incessant locomotion, were this organ constructed as it is in man. The well-being and ease of the animal is provided for by an exceedingly curious conformation. Taken altogether, the stomach is of prodigious extent in all the tribes of this class. It is divided into four distinct compartments, forming four separate bags (*fig.* 36): into the first of these, which is termed the paunch, (*fig.* 36, AA) the food is swallowed, as it is collected, with little mastication. In this bag it is macerated in a considerable quantity of fluid at a moderately high temperature. From the paunch it passes into a smaller bag, called the reticulum (*fig.* 36, B): from the reticulum it is again returned into the mouth, where it is masticated a second time, and now completely comminuted; and this is the process termed "rumination." In this manner the ruminant animal fills its capacious paunch with nutrient matter after having slightly masticated it; it then betakes itself to

rest, and at its ease returns its food a second time into its mouth in a macerated and softened state, in order to be completely masticated; after this perfect mastication, it is again swallowed: but it does not enter a second time either into the first or the second bag, but passes into the third (*fig.* 36, C), which is called the omasum, where it undergoes further and

Fig. 36.

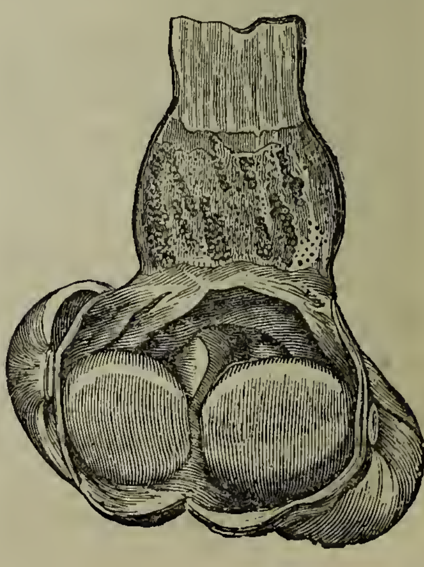


G, the gullet; A, A, the paunch; B, the reticulum; C, the omasum; D, the abomasum; E, the pylorus; F, the commencement of the small intestines.

specific changes, and from the third it passes into the fourth, (*fig.* 36, D), termed the *abomasum*, which last is perfectly similar both in structure and function to the simple stomach of the other mammalia and of man. It has been already stated that the intestines are always capacious and long in proportion as the food to be digested is less analogous to the substance of the animal it is intended to nourish: thus, in some species of ruminant animals, as in the ram, this tube is twenty-seven times the length of the body, while in carnivorous animals it is short and straight; the food on which they feed being already nearly of their own nature, and containing a large quantity of nourishment in less bulk, a smaller proportion both of time and space are required to fit it for use.

In graminivorous birds there is a still more curious modification of this part of the digestive apparatus. The entire organization of the bird is constructed with a reference to lightness, in order to adapt it for flight. Many birds are carnivorous. In these tribes there was no peculiar difficulty, because their food being already analogous to their own nature, it was only necessary to make the menstruum by which it is dissolved powerful and abundant to dispense with mastication altogether, and yet to dispose the stomach and intestines in smaller space; and this is the plan adopted. But a great number of birds live upon vegetable matter, and cannot be brought to subsist on animal food. It was utterly impossible to give to a creature fitted for flight, the enormous stomach and intestines of the herbivorous quadruped. Were the bird furnished with teeth, the general conformation of the class must also be departed from. Thus the bird is to live upon vegetable matter, to be destitute of teeth to masticate its food, and at the same time its stomach and intestines are to occupy only a small compass. How are these different and opposite objects to be effected? They are accomplished by a modification of the digestive apparatus, so simple and yet so effectual, that it cannot be contemplated without admiration. In the first place, the food of the bird, though of a vegetable nature, is not in general grass which contains the smallest proportion of nutritive matter in a given bulk, but grain which contains the largest. Then, in order to obviate the necessity of teeth, to dispense with the process of rumination, and to accomplish the resolution of hard grains and seeds into a soft and pultaceous mass, the following expedient is adopted. In the first place a membranous bag is provided, called the crop or craw, which receives the food from the mouth, slightly softens it by a mucous fluid

Fig. 37.



secreted from its internal surface, and thus prepared, it is transmitted into the organ called the gizzard, one of the most curious structures in the whole animal economy (*fig.* 37). The gizzard is composed of thick and tough muscular substance, small in size, but more powerful in its action than the strongest jaw bone. It consists of four distinct muscles, a large hemispherical pair at the sides, and a small pair at the two ends of the cavity. By their alternate action, these muscles produce two effects; the one a constant friction on the contents of the cavity, the other a pressure upon them. These muscles are lined with a cuticle which is extremely callous, and which often becomes cartilaginous and even horny. The prodigious power with which these muscles act, and the callous nature of the cuticle that lines them, were shown in a striking manner by Reaumur and Spallanzani. These distinguished physiologists in the course of their experiments compelled geese and other birds to swallow needles, lancets, and other hard and pointed substances. In a few hours after the experiment, the birds were killed and examined; the needles and lancets were uniformly found broken off and blunted, without the slightest injury having been sustained by the stomach. Many of these species assist the action of the gizzard upon the food by swallowing pebbles, which in some measure serve the purpose of teeth, and some tribes cannot digest their food without this aid. Mr. Hunter observed that the size of the pebbles is always in proportion to that of the gizzards. In the gizzard of the turkey he counted two hundred: in that of the goose a thousand. The more the student of nature contemplates these modifications, and the more the physiologist succeeds in discovering their use, the more perfect and beautiful the adjustments appear.

Of the Function of Digestion.

The assemblage of organs which has been described, constitutes the apparatus of digestion: their action by which they produce the requisite series of changes upon the aliment constitutes the function.

In expounding this function we shall first consider the changes themselves; and, secondly, the means by which they are effected. Under the first head will be adduced the particular facts, or phenomena of digestion, and under the second will be given an account of the theories which have been invented to connect and explain them.

Digestion may be defined to be that process by which the aliment is subjected to a certain succession of changes, by means of which it is fitted for nutrition.

Aliment is either solid or fluid; the process for producing the requisite changes in each is considerably different.

Of the Digestion of Solid Aliment.

In the digestion of solid aliment the following changes take place, and in the following order:—The food received by the mouth undergoes a great degree of comminution and softening by the organs of mastication. When thus duly prepared, it is transmitted to the stomach by the act of deglutition. In the stomach it is converted into a uniform and almost fluid mass, which is termed chyme. The chyme passes from the stomach into the first intestine or duodenum (*fig.* 32, D, E, H), in which organ it undergoes a further change. By the action of certain secretions which are here added to it, it is separated into two distinct and exceedingly different substances, one of which is termed chyle and the other fæcula. The chyle is the nutritive portion of the aliment, and is conveyed by a particular set of vessels, the structure and the course of which are hereafter to be described, into the blood. The fæcula is that portion of the aliment which is not conducive to nourishment, and which is conveyed out of the body. The conversion of the crude aliment into these different substances involves processes of great complexity and obscurity; but the accumulated observations and experiments of physiologists have put us in possession of many curious and important facts relative to the phenomena which take place, and to their order of succession.

Of the Mastication of the Food.

The first part of the digestive process may be considered as entirely mechanical. From the comparative view which has been exhibited of the apparatus for mastication, we learn, that whatever be the structure of the animal, and whatever the nature of the aliment on which it subsists, it is furnished with appropriate organs for the purpose of breaking down or minutely dividing its food. Sometimes this object is accomplished

by mastication; at others by trituration; at others again by a combination of both actions: but whatever be the expedient, the result is uniformly the same—the minute division of the aliment. This preparatory step is analogous to that which is necessary to many chemical combinations. Substances which are capable of exerting on each other the most powerful action, frequently produce no change whatever until the attraction of cohesion is diminished, and at other times not until they are reduced to a softened state. Great care has been taken in all animals to bring the food into both conditions before it is transmitted to the organ in which the proper digestive process is performed. We have seen that in man, the membrane which lines the whole internal surface of the mouth secretes a mucous fluid which is mixed with the food; that mucous follicles, situated in different parts of the mouth, continually pour out a considerable quantity of the same kind of fluid, and that there are in addition six large glands, termed salivary, three placed on each side, the special office of which is to prepare the saliva, which, as has been stated, flows in such abundance during mastication that according to the common estimation it amounts to upwards of eight ounces during a single meal. It can scarcely be doubted that the maceration of the crude aliment in a fluid thus abundantly and especially provided for the purpose by secretion, exerts some influence over it beyond that of merely softening it.

Of Deglutition.

When the food is completely comminuted, and sufficiently softened by imbibing the fluids of the mouth, it is conveyed into the stomach by the action of deglutition. Deglutition is not a mechanical, but is altogether a vital action. The food does not descend through the œsophagus by its own gravity, but is propelled by muscular contraction. Few parts of the animal structure exhibit a more beautiful specimen of mechanism than the arrangement and action of the organs that are concerned in this function. Simple and easy as it appears, it is really extremely complicated: it is produced by the contraction of a great number of muscles, and it requires the concurrence of several very important organs. Each part of the apparatus produces an independent specific effect, and the result of their combined action is the attainment of the object in the most perfect manner.

As soon as it is sufficiently comminuted by the teeth, the aliment is collected together and moulded into a suitable form by the combined action of the muscles of the cheeks and tongue. Thus prepared, the morsel is conveyed by the action of these organs to the dorsum, or upper and back part of the tongue, and the tongue pressing with its apex against the palate as against a fulcrum, conveys it into the pharynx, a musculo-membranous bag situated in the back part of the throat (*fig.* 38, *a a a*). By one

Fig. 38.

Represents the back part of the head with the ears: or a posterior view of the pharynx, and other parts described; *a, a, a, a,* represent the the bag of the pharynx cut open in order to allow the other organs to be seen; *b,* the continuation of the bag of the pharynx, which is seen to be contracted into the form of a tube, called the œsophagus, and which terminates in the stomach; *c,* the glottis; *d,* the epiglottis; *e,* the trachea. Other cavities are seen opening into the great bag of the pharynx; two above which represent the openings into the pharynx from the nostrils, and one below from the mouth.

set of muscles, with which it is in connection, the pharynx, the moment the tongue is ready to transmit the morsel to it, is drawn upwards in order to receive it; and by another set of muscles it is also at the same instant expanded, this simultaneous elevation and opening

of the bag being indispensable to its reception of the food. Having received the morsel, the muscles of which the pharynx is composed are stimulated to contraction by its contact. By the contraction of these muscles the morsel is compressed and propelled into the œsophagus, which latter organ is constantly kept in a moistened state by mucous fluid, which considerably facilitates the passage of the food. Numerous other openings (*fig.* 38), several of them of considerable size, and which are connected with organs that perform some of the most important functions in the economy, are situated either in the pharynx, or in its immediate neighbourhood. It was necessary to guard with special care against the entrance of the food into either of these openings, for such an event would be attended, in any case, with great inconvenience, and in some, with almost instant death. The variety, the simplicity, and yet the efficacy of the expedients which are adopted to prevent such an occurrence, cannot be contemplated without the highest admiration.

From the pharynx the food is conveyed, as we have seen, to the œsophagus (*fig.* 38, *b*). The superior part of the œsophagus, which is continuous with the pharynx, is, like it, at first expanded to receive the morsel, and is then excited to contraction by its contact. By this contraction it is propelled onwards ; the mucus with which the entire surface of the œsophagus is lubricated facilitating its passage, while the pressure of the morsel above first of all distends that part of the œsophagus which is immediately below, and then by its presence simulates its muscular fibres to contraction. By these alternate dilatations and contractions the morsel is at length propelled into the stomach.

On carefully observing these successive actions, it is found that the morsel passes with very different degrees of rapidity through different parts of its course. On watching the action of the organ, Boerhaave was so struck with the extreme rapidity of its motion, that he said, the food is transmitted through the pharynx by a convulsive action of its muscles. The necessity of this will be perceived, when it is remembered that the larynx, the commencement of the air-tube of the lungs, is placed before the pharynx (*fig.* 38, *d,c,e*) ; that this air-tube must necessarily be closed while the food passes over it, and that the closure of its opening, only for a few seconds, would materially obstruct the function of respiration, one of the most indispensable functions of the animal economy. M. Magendie has shown that the progress of the food through the œsophagus is exceedingly different; that it occasionally stops at different parts of the passage; that it remains some time at each station, and is often two or three minutes in reaching the stomach. For the reason just assigned, were this delay to take place in the pharynx, it would inevitably occasion death. Deglutition, then, consists of three distinct stages ; first, of the passage of the food from the mouth into the pharynx ; secondly, from the pharynx into the œsophagus ; and thirdly, from the œsophagus into the stomach.

Of the Arrangement of the Food in the Stomach.

We owe to Dr. Wilson Philip an interesting account of the phenomena which take place immediately after the food is received by the stomach The alimentary mass passes first into the cardiac portion of the organ (*fig.* 30, *b*). It is in this part of the stomach that digestion is most actively performed. In cases of sudden death, after a full meal taken, when the person was in sound health, the coats of the stomach itself are apt to be digested : but this digestion of the organ is most commonly found in its cardiac portion. Dr. Philip states, that if a rabbit be killed soon after eating a hearty meal, the cardiac extremity will be found completely digested in almost every instance ; but that, in the numerous experiments he has performed, he never saw the coats of the organ eaten through, excepting at its large end. Although, after death, the stomach must be equally subject to the action of the gastric juice as any other dead animal matter, yet it is not a little extraordinary that the gastric juice of the rabbit which, in its natural state, refuses animal food, should be capable of digesting its own stomach, so completely as to leave not a single trace of the parts on which it has acted.

The digestion of the food always takes place from the surface towards the centre of the mass : the nearer it lies to the surface of the stomach the more it is acted on, and that part of it which is in actual contact with its wall is more digested than any other portion.

The new food is never mixed with the

old: the new is always found in the centre, surrounded on all sides by the old: if the old and the new are of different kinds, the line of separation between them is so evident that the old may be completely removed without disturbing the new; and if they are of different colours, that line can often be distinctly traced through the walls of the organ before it is opened.

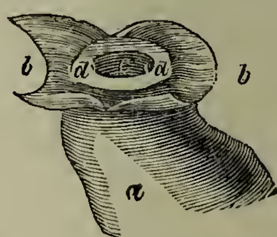
In proportion as the food is digested, it is gently moved along from the cardiac (*fig.* 30, *b*) towards the pyloric end (*fig.* 30, *e*). As the layer which lies next the surface of the stomach first undergoes the requisite change, and is propelled onwards by the muscular action of the organ, so the portion which lies next it succeeds in turn to be submitted to the same process. The gastric juice, at the same time, pervades in a greater, or less degree, the entire alimentary mass, so that when the central part comes into contact with the surface of the stomach, its digestion is already considerably advanced.

The food remains in the stomach upwards of an hour before any change in it becomes perceptible. It is commonly stated that a meal is completely digested in the human stomach in about four or five hours. If this statement be correct, the digestion in other animals is much slower. In experiments performed on dogs which had eaten as much flesh as they chose, and which were killed six hours after the meal, it was found that the stomach was still nearly full, and that the surface of the food next the wall of the stomach was acted on throughout in the manner just described. From the experiments of Dr. Philip, it appears that, in the rabbit, the central part of the mass of food in the cardiac portion of the stomach was not as much digested as that next the surface of the organ, until the animal had fasted sixteen or eighteen hours. And Sir Everard Home states that the stomach of this animal is never completely empty, but that when it dies after fasting, however long continued, it is always found to contain a considerable quantity of food.

It has been stated that, as the aliment is digested, it is gradually accumulated at the pyloric extremity of the stomach. This portion of the food has experienced the most complete digestion which it is capable of undergoing in this organ, and is termed chyme. Chyme is a pultaceous and almost fluid substance, of a greyish colour, of a sharp odour, and of an acid taste, reddening paper coloured with turnsole. It is commonly said to be perfectly homogeneous in its nature; and that, whatever be the species of the food, the resulting mass is uniformly the same, never exhibiting any of the sensible properties of the crude alimentary matter. But this statement is not correct: for we learn by actual experiment that chyme produced from vegetable differs in colour, in consistence, and in some other sensible properties from that procured from animal substance.

When thus completely formed in the stomach, the chyme is gradually propelled by the alternate contraction and relaxation of the muscular fibres of the organ towards its pyloric extremity (*fig.* 30, *e*). Here it accumulates in a certain quantity before it is permitted to pass through the pylorus: which, as has been stated, consists of a ring of muscular fibres, of the structure and arrangement of which it is impossible to convey an accurate idea by any plate; but the position of which is represented by the white ring, marked *d*, *d*, in *fig.* 39; while its opening, through which the chyme passes, is pointed out by the

Fig. 39.



a, pyloric extremity of the stomach; *b*, *b*, section of the beginning of the duodenum; *d*, *d*, the ring of muscular fibres constituting the pylorus; *c*, the opening of the pylorus, through which the chyme passes from the stomach to the duodenum.

Fig. 40.

Represents the pylorus in the natural state, in which it is more contracted than when distended and dried.

letter *c*. It would appear that the accumulation of the chyme at this extremity of the stomach, never exceeds four ounces at any one time. M. Magendie states that in the numerous experiments in which he has had an opportunity of observing it, he has uniformly remarked that when it amounts to about two or three ounces, it is admitted through the opening of the pylorus into the duodenum (*fig.* 39, *b b*). Nothing in the animal economy is more curious and wonderful than the action of that class of organs of which the pylorus affords a remarkable example. If a portion of undigested food present itself at this door of the stomach, it is not only not permitted to pass, but the door is closed against it with additional firmness: or, in other words, the muscular fibres of the pylorus, instead of relaxing, contract with more than ordinary force. In certain cases, where the digestion is morbidly slow, or when very indigestible food has been taken, the mass is carried to the pylorus before it has been duly acted on by the gastric juice: then, instead of inducing the pylorus to relax in order to allow of its transmission to the duodenum, it causes it to contract with so much violence as to produce pain, while the food thus retained in the stomach longer than natural disorders the organ; and if the digestion cannot ultimately be performed, that disorder goes on increasing until vomiting is excited, by which means the load that oppressed it is expelled. The pylorus is a guardian placed between the first and the second stomach, in order to prevent any substance from passing from the former until it is in a condition to be acted upon by the latter: and so faithfully does this guardian perform its office that it will often, as we have seen, force the stomach to reject the offending matter by vomiting rather than allow it to pass in an unfit state: whereas, when chyme duly prepared presents itself, it readily opens a passage for it into the duodenum. This eminently vital property of the muscular fibre, of most essential and varied use in the economy, by which it is obedient only to particular stimuli, will be further spoken of hereafter.

Of the Formation of Chyle.

In the duodenum the chyme undergoes a further change. After it has been a short time in this organ it is observed to separate into two parts, into a white fluid, which is detached from the common mass, and which constitutes the proper nutritive substance: this is termed chyle: and into a residual matter which is not nutritive, but which is ultimately converted into fæces and rejected from the system. We are as ignorant of the mode by which chyme is converted into chyle, as of that by which the crude alimentary matter is changed into chyme: but as the agent by which the former is produced may be considered as ascertained, so that by which the latter is effected may be stated to be known with a high degree of probability. It is observed that the chyme, soon after it enters the duodenum, is mixed with two specific secretions, that of the pancreas (*fig.* 35, C), which is termed the pancreatic juice, and that of the liver (*fig.* 32, A A), which is called the bile. In living animals the bile is seen to exude, at intervals, from the excretory duct of the liver termed the *ductus communis choledochus* (*fig.* 32, F). A drop appears at the orifice of the canal, and diffuses itself over the neighbouring surface about twice in a minute. It is remarked that the pancreatic secretion is admitted to the intestine through the pancreatic duct (*fig.* 32, G) still more slowly. The chyme is observed to be accumulated in the greatest quantity about the orifice of the *ductus communis choledochus*. The moment the bile is mixed with it, a striking change takes place in the entire mass: it loses its own sensible properties, and acquires those of the bile, especially its colour and bitterness. In a short space of time a spontaneous change is observed to take place in the compound: it separates into a thick, whitish, cream-like fluid, and into a yellow pulp: the white fluid is the chyle; the yellow pulp is the excrementitious portion. Both together are now slowly carried along the small intestines (*fig.* 32, K K). The chyle thus separated from the chyme, is found already to possess the most remarkable property of the circulating blood, namely, that of coagulation. It is observed to adhere with some tenacity to the internal or mucous coat of the intestine; for if this portion of the canal be examined in an animal killed after having recently taken food, this matter will be found in a state of coagulation adhering with considerable firmness to the mucous coat. This adhesion of the chyle to the surface of its containing tube, does not appear to arise from any

adhesive property in the chyle itself, but is supposed to be rather the effect of a species of attraction exerted by the mucuous coat for this peculiar matter: to be a vital action referrible to a class of vital actions highly curious in their nature, of which the animal economy affords numerous examples. It was necessary that the nutrient matter should be brought into a certain degree of contact with the mucous surface of the intestine, and should be held in contact with it for a certain length of time, in order that the lacteal vessels might have the means of absorbing it: the mucous membrane of the intestine is therefore endowed with the power of attracting this matter to itself: thus exhibiting a beautiful example of that peculiar relation, or, as it is sometimes termed, consent between containing and contained parts which is so characteristic of life. The progress of the chyle through this part of the canal, is likewise rendered slower by the folds of the mucous membrane, termed the *valvulæ conniventes* (*fig.*34). As it passes along the tube it gradually disappears, becoming smaller and smaller in quantity, until at length it is nearly lost at the point where the small intestines terminate in the large (*fig.* 33, E). The yellow pulpy substance forming the excrementitious part of the aliment is transmitted from the ileum, the last of the small intestines to the cœcum, the first of the large (*fig.* 33, E); whence it passes through the whole tract of the latter, and is finally conveyed out of the body in the form of fæces.

The chyle nearly approximates to the nature of the blood. Like it, when removed from the body, as has just been stated, it spontaneously coagulates; that is, it separates into a dense whitish mass termed the coagulum, and into a transparent colourless fluid. The basis of the coagulum is found to be a substance closely resembling the fibrine of the blood, and the fluid part to be very similar to its serum: it exhibits the same chemical properties as the corresponding parts of the blood, and it also resembles this fluid in the nature of its salts: but all these circumstances will be better understood after the blood has been described. It has been already stated that when the chyle is examined with the microscope it is found to consist of innumerable globules; that these globules have been examined with great diligence by Dr. Edwards, who informs us that they are exactly of the same magnitude, and possess precisely the same physical properties as the central globule of the blood when divested of its external colouring envelop. This distinguished physiologist likewise maintains that both the globule of the chyle and the central globule of the blood exhibit precisely the same physical properties as the globules that compose the primitive tissues of the body; and that thus, as soon as the fluid which is destined to nourish the body is formed, the organic molecules of which the body itself consists are discoverable in it. Later microscopical observations, however, place in considerable doubt the accuracy of those which have preceded.

Of the Digestion of Fluids.

Fluid substances obviously require to be subjected to none of the preparatory processes which are indispensable to the digestion of solid aliment: they need no mastication and no admixture with the liquids of the mouth. Their deglutition is more easy and rapid on account of their greater divisibility. The series of changes they undergo in the stomach, is by no means well understood. It is ascertained that they remain a much shorter time in the stomach than solid aliment. If the stomach of an animal be examined very shortly after it has drunk copiously, it is found completely empty of fluid. Until lately, it was supposed that fluids like solids are transmitted from the stomach to the duodenum through the opening of the pylorus, and their rapid disappearance was accounted for from their finding a ready passage through the pylorus, on account of their easy divisibility. But M. Magendie has shown that if a ligature be placed around the pylorus, so as to prevent the possibility of their exit through that aperture, they disappear from the stomach with almost equal rapidity. Recently, professors Tiedemann and Gmelin have investigated this subject with great care, and they state in the most positive manner, that they have ascertained from numerous experiments, of which it is impossible to give any account in the present place, that the fluids of the stomach are rapidly taken up by the absorbents of the organ; that they are immediately conveyed by these vessels to the liver, and that they circulate directly through that viscus. The object of this curious

disposition is at present wholly unknown, and the fact itself cannot be received without further confirmation.

Of the Theories of Digestion.

The principal theories which have been invented to connect and explain the preceding phenomena are those of concoction, putrefaction, trituration, chemical solution, vital energy, and nervous influence.

The oldest hypothesis of digestion on record, is that of concoction, which was maintained by Hippocrates, and descended down through Galen to comparatively modern times. But concoction is only another word for digestion; and to say that the function of digestion is performed by the process of concoction is not to propose a theory, but merely to employ another word to express the process itself.

That digestion is not performed by a process analogous to that of putrefaction is proved by the facts that the first effects of the application of the gastric juice to the alimentary mass is to resist putrefaction, and to suspend the process even after it has actually commenced.

The mechanical physiologists endeavoured to account for all the phenomena of digestion by trituration. Calculations were made, apparently with mathematical accuracy, to ascertain the force that would be required for the performance of the function in this mode; and accordingly Pitcairn estimates that the force of the muscular fibres of the stomach is equal to 12.951 pounds. The facts which refute this hypothesis are already before the reader: namely, first that the stomach of most animals is entirely membranous, and cannot possibly exert the requisite power; and secondly, that digestion is performed under circumstances in which trituration cannot operate, as is proved by the experiments of Spallanzani, Stephens, and others, immediately to be detailed.

The theory of chemical solution is directly favoured by all the experiments that disprove the former hypothesis. The evidence that the stomach secretes a peculiar fluid, which acts chemically upon the aliment, and that nothing further is necessary to produce these actions, than to bring the two substances into contact, may be said to be complete. Among the numerous experiments which have been performed to establish this point, the most curious and important are the following.

Spallanzani inclosed different alimentary substances in metallic balls perforated with holes, and in pieces of porous cloth. These were introduced into the stomach, and after having remained there for a certain time were withdrawn: on their removal, it was found that the matters inclosed were more or less dissolved, while the containing substances, whether metal or cloth, were not acted upon in the slightest degree. Since this effect could not possibly be produced by mechanical means, there seems no other resource, but to suppose that it was accomplished by chemical agency.

By vomiting, mechanically excited, the same experimentalist threw up from his own stomach a tube perforated with holes, and containing beef which he had swallowed four hours before. The flesh was thoroughly soaked with the fluid of the stomach: its surface was soft and gelatinous: it had wasted from fifty-three to thirty-eight grains.

1. With a view of prosecuting these researches, Dr. Stephens took advantage of a man who had been in the habit of swallowing stones, and afterwards of rejecting them from the stomach. This experimentalist caused the man to swallow hollow metallic spheres, perforated with numerous orifices, and filled with different kinds of alimentary matter. By numerous experiments, it was established that when a hollow silver sphere containing raw or cooked flesh or vegetables, and perforated with holes that would admit a crow quill, was swallowed, it was rejected *per anum*, in about forty hours, and was always perfectly empty.

2. That the gastric juice acts chemically upon the food is proved by the fact that alimentary substances in the progress of digestion present precisely the appearances which they would exhibit were they exposed to the influence of chemical agents. It is truly stated by M. Magendie, that the surface of food undergoing the process of digestion consists of a soft layer which is easily detached from the undigested part, and which has every appearance of having been acted on by a re-agent capable of dissolving it, and that the white of a hard-boiled egg, for example, appears just as if it had been plunged in vinegar, or in a solution of potash.

3. The effect produced by the gastric juice on the substances exposed to it bears no proportion whatever to their mechanical texture, or to their other physical properties. While it acts upon

the densest membrane; while it speedily dissolves bone itself, it produces not the slightest effect upon many substances of the most delicate texture; the skins of fruit, for example, and even the finest fibres of flax and cotton are not in the smallest degree affected by it. This selection of substances exactly resembles the operation of chemical affinity, and is decidedly contrary to what would be the effect of mechanical agency.

4. The gastric juice produces, on certain substances, effects which unquestionably are of a chemical nature. Thus it occasions the coagulation of albuminous fluids, and prevents putrefaction. An infusion of the proper stomach of the calf, termed rennet, is commonly employed for the coagulation of milk, a small quantity of which converts the albuminous portion of milk into the state of curd. The antiseptic power of the gastric juice was abundantly established by the experiments of Spallanzani, who observed, that in carnivorous animals, which frequently take their food in a putrid state, the first operation of the stomach was to remove this fœtor. It was also found that if the gastric juice be added to substances out of the body, it resists their putrefaction, and even suspends the process when it has commenced.

But wonderful and irresistible as the action of the gastric juice is proved to be, it is destitute of any sensible properties upon which its power can depend, or with which its agency can be connected. According to every test which it is in our power to apply to it, it appears to be exceedingly analogous to saliva, or to the ordinary secretions of the mucous membranes,—fluids which, so far from indicating any active properties, are remarkable for their blandness. This apparent inertness has suggested doubts whether it really possess the active agency which is attributed to it, and has led to the institution of experiments to ascertain whether it is capable of producing effects out of the body analogous to those which it accomplishes within the stomach. In order to learn whether chyme can be formed by the gastric juice out of the stomach, Spallanzani procured this fluid from the stomachs of various animals; and on mixing it with different alimentary substances, it was found that it actually does exert an influence very similar to that which is supposed to take place within the stomach. Some of this fluid was put into a glass tube with boiled beef that had been masticated; the tube was then hermetically sealed and exposed near the fire to a considerable heat; by the side of this tube was placed another, containing the same quantity of flesh immersed in water. In twelve hours the flesh in the tube containing the gastric juice began to lose its fibrous structure; in thirty-five hours it had entirely lost its consistence; it appeared, as far as the eye could judge of it, to be reduced to a pultaceous mass, and no further change was produced in it by the gastric fluid during the two following days. On the other hand, the flesh that had been immersed in water was putrid in sixteen hours. Although it is impossible to imitate out of the stomach several very important circumstances which occur in the natural process, yet this experiment appears to have accomplished a near approach to chymification; and upon the whole, what has been stated, may be said to present a chain of clear and satisfactory evidence leading to the general conclusion that the food in the stomach is converted into chyme by the fluid secreted from its surface, and that this change is effected by a proper chemical action.

Dr. Prout has recently discovered, that during the process of chymification, muriatic acid is always present, a fact confirmed by the testimony of professors Tiedemann and Gmelin, who state that in all their researches they uniformly detected the presence of an acid. Occasionally heat, and not unfrequently gas, are also evolved; but whether these products form a necessary part of the process when exercised in a perfectly healthy manner, or whether and how far they arise from a morbid condition of the function, is not ascertained.

Some physiologists are of opinion that it is possible to advance a step further, and to determine the particular kind of chemical action by which the gastric juice produces the requisite changes in the food. They think the facts observed warrant the conclusion that it acts as a specific ferment. In chemical solution, two bodies act upon each other and produce a third substance possessed of new properties; in fermentation, the elementary principles of bodies are disengaged, and enter into new combinations. Now, since there is reason to believe that every compound substance must be de-

composed in order to fit it for nutrition, it is argued that this very reason seems to justify the conclusion, that the process of digestion does not consist in their chemical solution, but in a specific fermentation. And it is further stated in favour of this view, that there are several specific fermentations with which we are acquainted; for example, the vinous, the acetous, the paniary; and that there are probably others which are at present unknown, of which what may be termed the chylous may be one. It must be admitted, however, that while there is much probability in this supposition, and while the evidence can scarcely be resisted that digestion is performed by a chemical action of some kind, yet that we are at present wholly ignorant of the particular nature of that action.

From the difficulty of accounting in a satisfactory manner for this process either upon mechanical or chemical principles, some physiologists have ascribed it to the agency of what they have termed the vital principle. The internal surface of the stomach, they say, is endowed with a specific property which belongs to it as a living substance, and which enables it to digest the food. When the meaning of this language is strictly analyzed, it will be found to amount to no more than that the process of digestion is peculiar to the condition of life, and that it is never observed to take place in any other state. But this, like the ancient doctrine of concoction, is merely the adoption of a peculiar mode of expressing the fact, and not a reference of the fact to an efficient cause.

Lately many observations and experiments have been adduced to show that digestion is essentially a nervous function, depending upon the direct agency of the nervous system. Thus it is ascertained by direct experiment that this process is suspended by dividing the eighth pair of nerves. Dr. Philip states that if an animal be allowed to live a considerable time after a part of this nerve is removed, the food remains unchanged in the stomach, and is nearly in the same state in all parts of the organ; that this effect is quite uniform, and that in all his experiments he has never seen it otherwise. This fact, which has been conceived to be decisive in favour of the nervous hypothesis, proves only that the influence of the eighth pair of nerves is essential to the secretion of the gastric juice, and therefore does not bear upon the subject of digestion, but merely upon that of secretion. And Dr. Holland has endeavoured to prove from Dr. Philip's own experiments, that the division of the eighth pair arrests the process of digestion, by interrupting the respiration, and consequently the circulation, and that it is thus through the lungs and heart that the secretion of the gastric juice is prevented. And it is remarkable, that if Dr. Philip's experiments be examined, it will be seen that the respiration was simultaneously affected with digestion.

Having thus considered the general facts to which the most eminent cultivators of this science have conceived that the particular fact of digestion may be referred, we shall conclude this subject by saying a few words relative to the different substances, on which the digestive organs are capable of acting, and by adverting to the true nature of the sensations of hunger and thirst.

Of the Food of Plants and Animals.

The proper food of plants is water and air: both are indispensable to the subsistence of this class of organized beings. Some plants indeed appear to subsist on air, and others on water only: but the äeriel epidendrum, without doubt, derives its moisture from the water suspended in the atmosphere. The quantity of air naturally mixed with water is found to afford an adequate supply of this fluid to some aquatic plants, but it is proved by direct experiment, that if totally excluded from air, plants uniformly die. Soils are not the food of plants: soils may be considered as the fixed abode of plants, and as the medium through which they receive a great portion of their nourishment. Soils are composed of earths, silica, lime, alumina, magnesia, the oxides of iron and manganese; they contain also vegetable and animal substances in a state of decomposition, together with saline, acid, and alkaline combinations. The fertility of a soil depends essentially upon its capacity to retain water: to hold it much in the condition in which it is retained in the sponge—that is, not in a state of aggregation, but of minute division; so that every part may be moist, but no part wet. Earths, beside affording the requisite degree of adhesiveness and looseness to retain and distribute moisture in this manner, fix the plant in the ground, and support it

therein. Whatever other useful purposes the admixture of mineral substances in the soil may accomplish in the economy of the plant, it is probable that they act as stimulants upon the capillary rootlets, and that they may be to the plants what condiments are to the animal.

Plants are interposed between the inert soil and the living being, between inorganic and organic matter; and appear to be the great laboratories in which are formed, out of inorganic materials, those elementary organic particles by the assimilation of which the higher classes of living beings exist. Consisting, for the most part, of organic particles, which are capable of being assimilated in the digestive organs of animals, vegetables in general are adequate to the support of animal life. Vast tribes of animals, however, subsist entirely on animal matter; and there are correlative tribes, the main purpose of whose existence seems to be to convert vegetable into animal matter, in order to afford the materials of support to those endowed with higher organization. As the vegetable prepares organic particles from inorganic matter, so these animals appear to convert the particles thus organized into animal substance, that the process of assimilation in the higher animals may be shortened. Large tribes of animals, however, high in the scale of organization, live entirely upon vegetable matter; others subsist solely upon animal substance; while others are supported in the most perfect health and vigour by a combination of both. We have seen that the digestive organs of animals which live on vegetable matter differ considerably from the digestive organs of those which are supported by animal substance. The successive changes that are necessary to the complete digestion of vegetable matter are more numerous; and hence in all herbivorous animals the alimentary canal, as we have seen, is much larger and more complicated than in those which subsist on animal food.

We know that in the digestive organs of an animal, the vegetable is changed into animal matter, and that the vegetable has the power of reconverting animal into vegetable substance: hence the utility of manure in promoting the process of vegetation; some kinds of manure consisting almost entirely of animal matter in a state of decomposition. We have seen that both vegetable and animal matter consists of the same ultimate elements differently arranged, and combined in different proportions, and that every article of food must undergo a complete decomposition before it is fitted for the purpose of nutrition. We may conceive, then, that in the process of vegetable digestion, the ultimate elements are enabled to enter into those peculiar combinations which constitute vegetable matter; and that in the process of animal digestion they are enabled to enter into those which constitute animal matter; these combinations depend on the attractions which different species of matter exert: these attractions differ according to circumstances. In the stomach of an animal, the elements of alimentary substances being disengaged, we must suppose that circumstances are always so arranged as to secure by the affinities of these substances for each other, just such a recombination of them as is necessary to constitute chyme. This, it is true, amounts to nothing more than an expression of the fact, and affords no explanation of this most curious and mysterious process; but still this mode of expressing it may enable us to form a just conception of the nature of the fact itself.

It has been stated that both vegetable and animal matter consists of the same ultimate elements, namely, oxygen, hydrogen, carbon and azote; and that, of these, vegetables in general contain three only, being for the most part destitute of azote or nitrogen, or containing it only in small quantity. They have also less hydrogen; while on the other hand they contain a much larger proportion of carbon.

It has been further stated that the ultimate elements of vegetable and animal substances combine together in different proportions, and thus form different products; and that from the most simple of such combinations, certain substances result, which, on account of the simplicity of their composition, are called Primary Compounds, or Proximate Principles. The most important primary compounds or proximate principles of vegetable origin are, gluten, farina, mucilage, oil, and sugar. These substances possess very different nutritive properties. Gluten is by far the most nutritious of them all; its elements most nearly resemble those of animal matter: it contains nitrogen in considerable quantity—the element which has

been stated to be absent from almost all the vegetable products. Of all vegetable substances, gluten is found in the greatest proportion in wheat.

Next to gluten, in the property of affording nourishment, is farina. This, likewise, is found most copiously in wheat. It also forms a considerable portion of the nutritive parts of various kinds of pulse and of tubers.

Leaves, stalks, seed-vessels, and the green parts of plants, afford the principal nourishment to many species of animals. The nutritive principle contained in these articles of food resides chiefly in mucilage, though to this is commonly united a portion of saccharine matter which contributes materially to its nutritive power. Most fruits contain a basis of mucilage, or farina, which is combined either with sugar or with oil. Sugar is among the most highly nutritive of all the vegetable products, and oil seems capable of being converted almost wholly into nutrient matter.

The most important of the proximate principles of animal origin which are employed as articles of diet, are fibrin, albumen, jelly, oil, osmazome, or the extractive matter of the muscular fibre which seems to give the specific flavour to the flesh of different animals: it is probable that it consists only of fibrin slightly altered by heat. There are some others, but they are of little consequence.

Articles of diet may be contemplated in two points of view, as nutritive, and as digestible. They are nutritive in proportion to their capacity of affording the elements of chyme: they are digestible in proportion to the facility with which they undergo the necessary changes in the stomach. There is an essential difference between these two properties, nor do they by any means bear an exact proportion to each other. Many substances which contain the elements of chyme in the greatest abundance are digested with difficulty; and it is remarkable that this difficulty is sometimes exceedingly lessened by mixing with them other substances that are less nutritive.

Animals, when in a natural state, adhere with remarkable uniformity to the same kind of food. There are many carnivorous animals which feed only on a certain kind of flesh; some upon the flesh of quadrupeds; others, again upon that of birds, and others upon that of insects. Among herbivorous animals, some subsist only on certain plants, others only on certain parts of particular plants, as the seed, the fruit, the leaves, and so on, while entire tribes of insects appear to be exclusively attached to some one species of vegetable matter. There is generally a manifest connection between the substances on which these animals feed, and the structure of the teeth, indicating that the selection is not the effect of accident, but depends upon the original conformation of the body. We have seen that the teeth of different animals are adapted, some for seizing and biting; others for tearing and lacerating; others for cropping the more succulent and delicate parts of plants, and others for masticating those that are firm and dense in their texture. The beaks of birds are infinitely diversified in their form and structure, some are long and pointed, others are broad and flat; others are hooked or curved. On carefully examining these diversities in their structure, it is found that each is adapted for receiving only certain kinds of food. And in all cases, the nature of the stomach, whether membranous, muscular, or ruminant; whether simple, consisting of one cavity only, or compound, divided into several distinct chambers, precisely corresponds to that of the teeth, and to the other organs and habits of the individual.

From whichever of these two great sources of nourishment the food of animals is derived in their natural state, nature has allowed to most of them a wide range in the power of abstracting it. Even those which most obviously and decidedly prefer one particular species of food, may gradually be brought to subsist well on the opposite; and man whose digestive organs evidently place him between those of carnivorous and herbivorous animals, has more power than any other of accommodating himself to widely different kinds of nourishment. Many observations and experiments show, that in him, at least, a mixture of various diet is not only consistent with health and vigour, but is highly conducive to both.

This point is abundantly illustrated by Dr. Stark of Vienna, who ultimately fell a victim to the zeal with which he prosecuted his researches, and who made himself the subject of a highly curious series of experiments upon the relative effect of various simple substances when used exclusively as articles of food for a long space of time. The

result showed that the body is invariably brought into a state of extreme debility by such a course of diet, and that there is not a single article of food, not even the most nutritious, that is capable of sustaining the vigour of the body, or even of maintaining life itself for any considerable period. By selecting one after another, single and simple articles of food, and by confining himself exclusively to one, this experimentalist so irretrievably ruined his health, as to bring on premature death.

M. Magendie has recently resumed these researches, and afforded additional evidence of the justness of the conclusion suggested by the experiments of Dr. Stark.

A dog, fed exclusively upon white sugar and water, appeared, for seven or eight days, to thrive well upon these substances: he was lively, and ate and drink with avidity: towards the second week, however, he began to lose his flesh, though his appetite continued good. In the third week he lost his liveliness and appetite. An ulcer formed in the middle of each cornea, which perforated it, and the humor of the eye escaped: the animal became more and more feeble, and died on the thirty-second day of the experiment. Results nearly similar ensued with dogs fed upon olive oil and distilled water; but no ulceration of the cornea took place, and analogous effects were observed in dogs fed upon gum and upon butter.

A dog, fed with white bread, made from pure wheat with water, died at the expiration of fifty days. Another, fed exclusively on military biscuits, suffered no alteration in its health.

Rabbits and guinea-pigs fed upon one substance only, as corn, hay, barley, cabbage, carrots, and so on, die, with all the marks of inanition, generally in the first fortnight, and sometimes sooner.

An ass, fed upon boiled rice, died in fifteen days, having latterly refused its nourishment.

Dogs, fed exclusively with cheese or with hard eggs, are found to live a considerable period; but become feeble, meagre, and lose their hair.

When a certain degree of emaciation has been produced by feeding an animal for some time upon one substance, as, for instance, upon white bread during forty days, the animal will eat with avidity different kinds of food offered to it at that period, but it does not regain its strength; it continues to waste, and dies about the same time at which its death would have happened, had the exclusive diet been continued; the digestive organs are irreparably injured, and the due stimulus though applied to them cannot now restore them.

M. Magendie adduces the preceding experiments to prove that a proportion of nitrogen is necessary for the support of animals. He conceives that the reason why the animals on which his experiments were performed, could not live for any length of time upon pure sugar, is because these substances are destitute of nitrogen. Dr. Bostock justly observes, that these experiments prove no more than that the stomach is not capable of digesting these substances without some addition. Dr. Stark's experiments furnish us with many examples of the indigestible nature of a diet composed of a single article, which was easily digested when mixed with other substances. In order to render M. Magendie's experiments decisive of the point for which he adduces them, it would be necessary to employ a diet, which should be composed of a mixture of substances —all of them without nitrogen—as farina, mucilage, or gum, mixed with sugar or oil.

These experiments abundantly prove the necessity of varying the articles of food. This necessity probably arises from the following cause, which the reader will understand better hereafter. The stomach, like other organs, can be excited to the due performance of its functions only by supplying it with an appropriate stimulus. By a long and uninterrupted continuance of one and the same alimentary substance, that substance probably loses its stimulating power, and thus, though it abound with nutritive properties, the stomach is incapable of acting upon it.

Sir Astley Cooper has made various experiments upon the digestibility of several substances which are commonly employed as articles of diet. He gave, for example, to dogs a determinate quantity of pork, mutton, veal, and beef, preserving a register of the figure of the pieces swallowed, and of the order of their introduction into the stomach. Opening the animals at the end of a certain period, and collecting with care what remained in the stomach, he ascertained that pork was the substance most rapidly digested; then followed mutton, then veal, and lastly, beef, which seemed to him the least digestible

of all. In some cases the pork and mutton had entirely disappeared, when the beef still remained untouched.

By other experiments he found that fish and cheese are also very digestible substances. Potatoe is somewhat less so; the skin which covers it passes into the duodenum without change.

He tried some experiments with the same substances prepared in different ways. He found that boiled veal is two-thirds more digestible than the same substance roasted. Divers other substances were likewise submitted to similar experiments. Thus he found that muscular flesh was sooner digested than skin; skin a little sooner than cartilage; cartilage sooner than tendon, and tendon than bone.

Some of the results of these experiments, but not all of them, accord with commonly received dietetic principles, and with the experience of dyspeptic persons. The human stomach, when weak and deranged, is usually observed to digest the lean part of pork and boiled mutton, more readily and with less inconvenience than any other animal substances.

There are several substances which, though they contain in themselves no nutritive property, yet exert a considerable influence in promoting digestion: these are commonly termed condiments. Condiments consist, for the most part, either of salts or spices; they probably act on the principle already stated, affording a stimulus to the stomach by which it is excited to a more energetic performance of its functions. Possibly, also, they may exert some corrective influence over the various species of aliment during the process of digestion. Thus the tendency of vegetable substanees to the acetous fermentation may be checked by aromatics and spices, and the tendency of animal matter to pass into a putrid state may be prevented by salts and acids.

Somewhat analogous to condiments in their effects upon the stomach, is the action of certain medicines, which, though they afford no nutriment, yet serve to put the stomach into a state which adapts it for the digestion of the aliment. There is this essential difference between articles of diet and condiments and medicines. No substanee, as has been stated, can contribute to nutrition, until it is resolved into its ultimate elements: condiments and medicines, on the contrary, act in their entire state, and cease to produce their appropriate effects the moment they are decomposed. The most virulent poisons, whether derived from the vegetable, the animal, or the mineral kingdoms, become perfectly inert when resolved into their elementary constituents. Dr. Fordyee observes, that certain insects live entirely upon cantharides, while their fluids are perfectly mild; and that even the poison of the rattle-snake is perfectly innocent when taken into the stomach.

An adult person, in sound health, taking moderate exercise, appears to require two hearty meals in the day: in states of disease a third repast is necessary; for the stomach, when weakened, digests food better if it be given in small quantity. In these cases, the adoption of the plan suggested by Mr. Abernethy is found in practice to be attended with the most beneficial effect—that of dividing the food to be taken in the day (suppose twelve ounces) into three equal portions, and taking each meal with strict regularity after an interval of six hours. It is astonishing how rapidly and completely the energy of the stomach sometimes returns under this treatment, in cases in which its function has been merely deranged, and to how great an extent suffering is relieved even when the total and permanent removal of it is hopeless.

During infancy and childhood, when an abundant supply of materials is required to build up the enlarging frame, the appetite is proportionably keen; the stomach appears to digest simple food more rapidly, and craves more frequent meals. Protracted exertion, with a scanty supply of nourishment, if not continued for so long a period as to destroy the tone of the stomach, produces in adults a voracious digestion resembling that of childhood. The digestive organs are fitted by such abstinence for the active service required of them in providing materials for the restoration of the frame.

Mr. Hunter was in the habit of quoting, in illustration of this point, the following extract from Admiral Byron's narrative. After describing the privations which he had suffered when shipwrecked on the coast of South America, the admiral incidentally mentions their subsequent effect upon his appetite. "The governor," says he, "ordered a table to be spread for us with cold ham and fowls which only we three sat down to,

and in a short time dispatched more than ten men with common appetites would have done. It is amazing that our eating to that excess we had done from the time we first came among these kind Indians, had not killed us, as we were never satisfied, and used to take all opportunities, for some months after, of filling our pockets when we were not seen, that we might get up two or three times in the night to cram ourselves."

Nothing promotes appetite more than moderate exercise in fresh air, and nothing is more adverse to it than sedentary occupations in close towns and ill-ventilated apartments; yet to such situations great numbers of the human race are doomed, and the effects are but too visible in their pallid countenances and their feeble frames; and but too acutely felt in the misery that results from the languid manner in which all the vital functions are performed. As long as society is constituted as it is at present, the great majority of the people appear to possess no means of escape from these terrible evils; nor are the distinguished few, whose success in the great struggle of life is commonly conceived to be the most complete and splendid, exempted from them. They may acquire wealth, and science, and fame, but the acquisition must be admitted to be dear, when the consequence is, as it too often is, the ruin of those physical organs, without the health and vigour of which there cannot be a moment's ease, nor the slightest degree of enjoyment.

Of Hunger.

Before concluding the subject of digestion, it may be proper to notice two affections of the stomach which are intimately connected with the process. The first of these is hunger. Hunger is a peculiar sensation which is universally referred to the stomach: the only cause that produces it, is a deficiency of food: it is commonly classed among the impressions which belong to the sense of touch, but it bears no kind of analogy to impressions belonging to this or to any other sense: it is altogether peculiar and specific.

Conceiving that its physical cause must be either mechanical or chemical, some physiologists belonging to the mechanical school have ascribed it to the friction of the sides of the stomach when it becomes empty. But from the description which has been given of the structure and position of the organ, it must be obvious that it is quite impossible for its different internal surfaces ever to come into forcible contact with each other. Besides, as has been just stated, the feeling of hunger is of a specific nature, and is totally different from the mere sense of resistance.

By the chemical physiologists, the sensation of hunger is accounted for by the action of the gastric juice upon the internal surface of the stomach, which they suppose to have a tendency to corrode it. The solvent power of the gastric juice, however, as we have seen, is confined to dead animal matter; and there is no reason whatever to suppose that it possesses any corrosive properties similar to those of a chemical acid.

It is probable that hunger is a peculiar perception depending on a specific impression conveyed to the brain by the nerves of the stomach, in the same manner as the impressions connected with the organs of sense depend upon peculiar impressions communicated to the brain by their appropriate nerves. It is also probable that the impression is produced upon the nerves of the stomach, through the intervention of the gastric juice, in a manner perfectly analogous to the action of light upon the retina. As light is the appropriate stimulus to the nerve of the organ of vision, so the gastric juice appears to be the appropriate stimulus to the sentient nerves of the stomach.

The sensation of hunger is in itself painful, and therefore may, at first view, appear to afford an exception to a general law of the animal economy, namely, that there is no arrangement for the purpose of producing pain, but on the contrary, that the natural and due exercise of all the organs is productive of pleasure. It has been much and justly insisted on, that of no contrivance in the body can it be truly said—"this is to inflame; this is to irritate." And yet the action of the gastric juice upon the sentient nerves of the stomach is painful, often highly painful; and it may be argued that the production of pain is the special object aimed at. A little consideration, however, is sufficient to show that this case falls under a very general law of sensation, namely, that pain arises, not when the stimulus which produces it is moderate, but only when it is in excess. Light admitted to the retina in moderate quantity is not pain-

ful but grateful: in great intensity, it is intolerable. In like manner the sensation of hunger, when moderate, is not painful but grateful: it is only when, from protracted fasting, the gastric juice accumulates and produces an excessive stimulus, that it becomes painful. And the object of this pain, or the use it serves in the economy, is too obvious to require notice. It is the monitor by which we are warned of the necessity of supplying the system with those materials which are requisite to renovate and maintain the integrity of the body. And it is a monitor whose voice it is not possible to disregard, for its importunity increases with the increasing demand occasioned by the wants of the system. It belongs to the class of affections termed appetites, and of which it has been justly observed, that they are distinguished by three remarkable characters. They are compounded both of a physical and a mental operation: they are connected with some evident useful purpose in the economy, and they are brought about by the intervention of the nervous system.

Of Thirst.

Thirst is a peculiar and uneasy sensation, which is commonly referred to the tongue and fauces, and which is conceived to depend upon a deficiency of the mucous secretions of those organs. There are circumstances which seem to show that the seat of this affection is more extensive. In a remarkable case published by Dr. Gairdner, of Edinburgh, it was found impossible to allay the thirst, merely by supplying the mouth, tongue, and fauces with fluid. A man had cut through the œsophagus: an insatiable thirst arose: several buckets-full of water were swallowed daily, and discharged through the wound, without allaying the affection: on injecting water mixed with a little spirit into the stomach, the thirst was quenched.

The sensation of thirst, like that of hunger, is a peculiar and specific perception; also, like it, depending on a specific impression conveyed to the brain by an appropriate set of nerves, and moreover perfectly analogous in the use it serves in the economy. The supply of fluids is, if possible, still more necessary than the supply of solids, to repair the waste of the system. Probably, on this account the demand is rendered more urgent by the greater intensity of the sensation, and by the acute pain occasioned by any considerable postponement in the gratification of the appetite.

Of the Blood.

We have seen that when the aliment is converted into chyme in the stomach, and the chyme is changed into chyle in the duodenum, the latter fluid is conveyed along the track of the small intestines, where it gradually disappears. It disappears, because it is absorbed by the mouths of innumerable vessels termed lacteals, hereafter to be described, which convey it by a route, which it will be more convenient to detail in another place, into the blood. Thus, the chyle is the fluid by which the blood is replenished; and in man, living in society, and taking his meals according to the general usage of civilized life, it is seldom that the formation of chyle is not going on in the economy, and that the vessels which transmit it from the intestines to the blood are empty or idle.

It has been stated that the chyle differs but little from the blood, excepting in colour, and that it exhibits some of the most peculiar and distinctive properties of this fluid. Other processes, indeed, which will soon be described, are still necessary to convert it into proper blood.

The blood is the common material of which all the tissues and all the organs of the body are built up. It is equally requisite to the formation of the most tender and delicate membrane, and to the construction of the hardest bone: it gives origin alike to the mildest and blandest fluid, as the saliva and milk, and to the most active and irresistible, as the gastric juice. It furnishes the new particles by which the capillary arteries, the masons and architects of the system, build up their different structures in the different parts of the body according to the wants of the economy. It affords the necessary stimulus to the great systems, especially the nervous and the sanguiferous, by which they are excited to the due performance of their functions—a stimulus, the interruption of the supply of which, even for a moment, causes them to languish, and the protracted interruption of which stops the machinery, and totally destroys it.

It is not wonderful, therefore, that life, even in the estimation of those who are entirely ignorant of anatomy and physiology, should be thought to reside especially in the blood. It is not won-

nerful that this opinion should have influenced the common language of mankind; that the term vital should, by common consent, be given to this important fluid, and that, with the word blood, the idea of life should be indissolubly associated. For these reasons, as well as on account of the most important part which the blood performs in every function of the animal economy, and the curious and interesting facts which have been ascertained relative to its composition, it is necessary that some account should be given of its nature and properties, although the full detail would occupy much more space than can be allotted to it in the present treatise.

Every one is acquainted with the appearance of the blood as it flows from a wounded blood-vessel: issuing from such a vessel, it is seen to be of a red colour, and of a thick and tenacious consistence. To a person who merely sees the stream as it flows, or who examines a mass of it collected in a cup, immediately after it is removed from a vein, two circumstances appear pretty evident; first, that it is a fluid substance; and secondly, that it is perfectly homogeneous in its nature. And yet it is not a fluid; or, at least, it does not long re main a fluid, for, in a few minutes, a large portion of it is converted into a tolerably firm solid; and, instead of being homogeneous in its nature, it is by far the most complicated substance in the whole body. Moreover, the mode in which its constituent parts are united is peculiar, and, in some important particulars, resembles nothing else with which we are acquainted. In describing this highly curious and important substance, we shall first of all consider its physical; secondly, its chemical; and thirdly, its vital properties. Although, at first view, it may not appear to be a natural arrangement to describe the properties of a substance without previously stating what are its component parts, yet the constitution of the blood is so peculiar, that we think even the account of the individual substances which enter into its composition will be more intelligible, and, therefore, more interesting, to the general reader, by the adoption of the order we propose to follow.

Of the Physical Properties of the Blood.

Among the physical properties of the blood may be enumerated its consistence, its colour, its specific gravity, and its temperature.

Of the Consistence of the Blood.

The blood, when it first flows from the vessels which contain it, is a thick, viscid, and tenacious fluid. All these properties vary in different species of animals; and in the same amimal at different periods, according to age, sex, health and disease. Soon after it has issued from its vessels, its consistence changes exceedingly, and it is converted, as has been stated, partly into a firm solid, and partly into a thin fluid. The means by which this change is *prevented*, as long as it is contained in its proper vessels, and by which it is *accomplished*, as soon as it is removed from them, belong to its vital properties, and will be explained hereafter.

Of the Colour of the Blood.

The blood in all animals is essentially the same, although it differs very considerably in colour in different classes. An equal difference prevails in the colour of the muscular fibre in different species of animals; yet all physiologists are agreed that there is no difference in the nature of the muscular fibre from the lowest animal, in which it can be traced, up to the highest. "Some animals," says Mr. Hunter, "have not that part of the blood which gives it the red colour, but the other parts, as the lymph and serum, as far as I yet know, are the same in all."

The nutritive fluid of the lower animals, then, although it be perfectly colourless, must still be considered as proper blood. In the insect this fluid is transparent: in the caterpillar it is of a greenish colour: in the internal vessels of the frog it is of a yellowish tint: in the higher classes of animals it is of a red colour; but even in these it is red only in certain parts of the body: thus, in fish it is red in the vital organs, as the heart, the liver, the branchiæ or gills, while the main bulk of the body, which consists of muscles, receives only a colourless fluid; and even in man there are parts of the body, the vessels of which are too minute to admit the red particles, as in some of the tunics of the eye, in the tendons and aponeuroses of muscles, and in the serous membranes. It is of the deepest colour in quadrupeds, although in some birds it is nearly as deep as in any class. It is deeper in some species than in

others: it is deeper, for instance, in the hare than in the rabbit. Even in the same species there is considerable diversity, and especially in man, upon which diversity many physiologists think the different temperaments, and in some measure, also, the various races of mankind, depend. Even in the same individual it is different at different periods, according to age, to disease, and even to different species of disease, so that, on the one hand, the pallidness, and, on the other, the duskiness of the skin, and the dark and livid colour of the cheeks, are alone sufficient to disclose to the physician the existence of some of the most formidable maladies to which the human body is subject.

It will be seen hereafter that the higher animals possess what is termed a double circulation: that is, one circulation from the heart to the lungs, and from the lungs back to the heart again; this is called the pulmonary circulation: and another circulation from the left side of the heart to all the parts of the body, and from all the parts of the body back to the right side of the heart; this is termed the systemic circulation. Now, the colour of the blood contained in the two sets of vessels which belong to each of these two systems of circulation is extremely different: in the one set it is of a dark or Modena red: in the other it is of a light scarlet colour. The vessels which contain the dark-coloured blood are called veins: the vessels which contain the scarlet-coloured blood are termed arteries. The veins convey the blood to the heart: the arteries carry out the blood from the heart, and distribute it to all the parts of the body: the arterial blood is the proper nutritive fluid: the venous blood is that which remains after it has been subjected to the various processes of nutrition, and which is carried back to the heart, and thence to the lungs, in order to be renovated, that is, in order to be reconverted into arterial blood. The changes which take place in the blood, and which occasion this striking alteration in its colour, will be described in the proper place.

It has just been stated that arterial, in contradistinction to venous blood, is the proper nutritive fluid; and, indeed, it is absolutely essential, both to the sustenance of life, and to the excitement of the vital organs to the due performance of their functions. If the circulation of arterial blood through the brain be stopped; if only venous blood be allowed to flow through its vessels, instant insensibility supervenes, and death follows in a few seconds. It is true, indeed, that venous blood is capable of nourishing some organs sufficiently to prevent them from perishing: an illustration of which is occasionally afforded by the peculiar disease of arteries, termed aneurism, which sometimes cuts off from a limb the supply of arterial blood: yet, in such cases, the member does not die, although it languishes, as all organs do languish, and many speedily mortify when they do not receive a certain quantity of arterial blood.

Of the Specific Gravity of the Blood.

The specific gravity of the human blood is estimated differently by different authors, probably because it differs in different individuals, and in the same individual at different periods. Taking water as 1000, the specific gravity of the blood may be stated to be about 1050: from this it may increase to about 1126. Haller stated its possible increase as high as 1527, but all modern inquirers are agreed in affirming that it has never been actually observed as high as 1126. The specific gravity is considerably altered by disease; the effect of disease is almost invariably to make it lighter: in one instance, on record, it was found as low as 1022. Dr. Davy states that arterial is lighter than venous blood: he estimates arterial at 1049, and venous at 1052. The more perfect the organization of the blood, or the higher the degree of vitality it possesses, the greater appears to be its specific gravity: for, in the higher order of animals, and in man, it is heavier than in the lower, and the effect of disease, as has just been stated, is, to lessen its weight.

Of the Temperature of the Blood.

The temperature of the blood differs considerably in different classes of animals. In cold-blooded animals and some quadrupeds the temperature is considerably higher than in man. In the sheep it is 102° or 103°, but of all animals it is highest in birds; in the duck it is 107°; and in man it is about 98°. It is said to be warm in proportion as it is near the heart. It is the general opinion that the blood of the artery is warmer by one degree than that of the vein. Disease is capable of affecting its temperature very considerably. In the cold fit of ague it has been

observed as low as 94°; and in some ardent fevers it has risen as high as 102°, or even, as some affirm, still higher. From some experiments of Hunter, he concludes that a moderate degree of inflammation is capable of raising it 4°, and an intense inflammation 7° above the natural standard. The power of all animals to maintain, with little variation, the temperature at which the functions of their economy are performed in the best manner, whatever be the temperature of the medium by which they are surrounded, has already been largely stated. But man, although, as has been shown, his natural temperature is much less than that of some other animals, has by far the greatest power of maintaining steadily his own temperature under intense degrees of cold, and still more intense degrees of heat.

Of the Chemical Properties of the Blood.

It has been stated that the blood is an exceedingly compound substance, consisting of many different ingredients which are held in union in a manner, in some respects peculiar; and that, when it first flows from the vessel, and for some time afterwards, it is fluid. At a certain period this fluid separates into two distinct parts—into a solid mass, and into a yellowish fluid in which the solid mass swims. The solid portion is termed the clot, or the crassamentum: the fluid portion is called the serum, and the process by which the separation takes place is denominated coagulation.

The period at which coagulation takes place varies according to a great variety of circumstances, which are chiefly interesting to the physician, and into the detail of which it is not necessary to enter at present. It is sufficient to observe, that the process commences in about three minutes and a half after the blood leaves the vessel, and is completed in from twelve to fifteen or twenty minutes. It is commonly stated that, upon an average, venous blood, in a state of health, is coagulated in seven minutes.

When first drawn from its vessel it possesses a temperature evidently greater than that of the atmosphere. As long as it retains its heat, an aqueous vapour arises from it, which is called its halitus, and which possesses a fœtid odour, which is much stronger in carnivorous than in granivorous animals. In the process of coagulation the blood is changed from a fluid into a solid, and, as in other processes in which a similar conversion takes place, there is an absolute extrication of caloric: for if, during the formation of the clot, a thermometer be moved first into the coagulated and afterwards into the fluid part, it will indicate a difference in the temperature of 6°; and if the system be suffering under a state of inflammation, of 12°. The relative proportions of the two constituent parts of the blood, the crassamentum and the serum, is variously estimated. It is difficult to obtain an accurate result, because the separation is incomplete, a portion of the serum always remaining attached to the crassamentum, while the proportion itself varies considerably in different individuals, and in the same individual at different times; but, as a general average, it may be stated that the crassamentum amounts to about one-third of the weight of the serum.

The crassamentum, after a certain time, further separates into two different parts, into a solid substance of a yellowish white colour, and into a red mass, to which the colour of the blood is owing. When the first substance is examined, it is found to be a solid of a considerable consistence, soft, yet firm, elastic, tenacious, so disposed to assume a fibrous arrangement as occasionally to form a net-work of fibres, and bearing in its general aspect, as well as in its chemical relations, a striking resemblance to pure muscular fibre, that is, to muscular fibre deprived of its enveloping membrane and of its colouring matter. This substance is designated by several names,—gluten, coagulable lymph, fibre of the blood, fibrin: the last is its most appropriate and, now, most common name. The second constituent of the crassamentum, the red matter which separates from the fibrin, consists of innumerable minute bodies of a rounded or globular figure, and which are termed the red particles or globules.

The specific gravity of the fibrin is greater than that of the serum, in consequence of which the former floats in the latter; yet the surface of both substances is always found nearly on a level, so that their specific gravity cannot greatly differ. On the contrary, the red particles are heavier than the fibrin, whence they subside during coagulation to its lower surface, forming the bottom of the clot.

The fibrin is by far the most impor

tant part of the blood: it is found in animals in which the red particles are absent: coagulation depends upon it: it forms the solid structures of the body: it constitutes the basis of muscle, and in the lower animals, which are destitute of the red particles, it probably performs the function of muscle.

Of the red particles, whatever be their nature and structure, it may safely be said that they are the least important part of the blood, although they have obtained the greatest share of attention, and have been the subject of innumerable observations and experiments. In many animals they are entirely wanting, and in all they are absent in some parts of the body.

When the smallest drop of blood is examined, the number of these particles contained in it appears to be countless: their magnitude is so minute that they can be distinguished only by the microscope. Their figure and bulk are different in different species of animals: in the reptile, the fish, and the bird their form is elliptical: in all the mammalia and in man they are circular. In the human blood the best observers are agreed in representing them as circular, flattened, transparent bodies, with a dark spot in the oentre, which is owing not to a perforation, but to a depression. They consist of an external envelop and of a central nucleus: the external envelop is red, and gives the red colour to the blood. The internal nucleus is colourless; the nucleus is independent of its envelop, for when the latter is destroyed the nucleus retains its original form. The nucleus is much smaller than the envelop, being, according to Dr. Young, only about one-third the length, and one-half the breadth of the entire particle. MM. Prevost and Dumas, who have investigated this subject with extreme care, and have arrived at several highly curious and important results, state that, in their view, the blood consists essentially of serum, in which are suspended a quantity of red particles: that each of these particles consists of an external red vesicle, which incloses in its centre a colourless globule: that during the progress of coagulation the external vesicle bursts and allows the central globule to escape; that, on losing their external covering the central globules are attracted together; that they are disposed to arrange themselves in lines and fibres; that these fibres form a net-work, in the meshes of which they mechanically entangle a quantity both of the serum and of the colouring matter; that these latter substances may be removed by draining and by ablution in water; that when this is accomplished there remains only pure fibrin: that, consequently, fibrin consists of an aggregation of the central globules of the red particles, while the general mass that constitutes the crassamentum, or clot, is composed of the entire particle. It is further stated by these distinguished physiologists that the colouring matter of the external envelop consists of a union of a peculiar animal substance of a gelatinous nature with the peroxide of iron.

Of all animals, the red particles are largest in the skate. In fish in general they are larger than in any other class. After fish, their magnitude is greatest in reptiles. In birds they are much smaller; and in man they are smaller than in any other animal. The estimation of their diameter in the human blood by different observers varies greatly. According to

Bauer, without colouring matter, . . .	$\frac{1}{1700}$ part of an inch.
Bauer, with ditto, .	$\frac{1}{2000}$
Wollaston, . .	$\frac{1}{5000}$
Young, . .	$\frac{1}{6060}$
Kalter, . . .	$\frac{1}{4000}$
Prevost and Dumas,	$\frac{1}{4076}$
Hodgkin, . .	$\frac{1}{3000}$

The blood of different animals differs exceedingly in the relative quantity of the red particles it contains: the number appears to bear an exact ratio with the temperature of the animal: the higher the natural temperature the greater the proportion of particles: arterial contains a much greater proportion of them than venous blood.

We have seen that innumerable particles are found in the chyle, and that the chylous particles are colourless. It is stated that the magnitude of these chylous particles is precisely the same as that of the central globule of the red particle of the blood. It is supposed that the chylous, colourless particles obtain their colour, and consequently their external envelop upon which it depends, in the lungs: it is, therefore, in this organ, that the process of digestion is completed, the chyliferous being here completely converted into sanguiniferous particles.

Of the Serum of the Blood.

When the fibrin separates from the

crassamentum or clot, it floats in a fluid which is termed the serum. Serum is a transparent homogeneous fluid of a light straw colour tinged with green, of saline taste and adhesive consistence. Its most remarkable and characteristic property is that of coagulation by heat and by certain chemical agents. At a temperature of 160° it is converted into a white and opaque substance, of tolerably firm consistence. In this state it exactly resembles white of egg when hardened by boiling, and is found to be of the same nature, whence it is termed albumen.

The proportion of serum to the crassamentum differs exceedingly in different species of animals, and in the same animals at different times, according to the state of the system. It appears to have a close relation to the strength and ferocity, or the weakness and gentleness of the animal, being, for example, much smaller in quantity in all the carnivora than in the sheep, the hare, and other timid animals. It is much increased in certain diseases: it is the fluid which is poured out into the different cavities in dropsy, while in some inflammatory diseases its quantity is considerably diminished.

With regard to its chemical properties, it contains a quantity of uncombined alkali, for it converts the vegetable colours to green. It holds in solution various earthy and neutral salts, which exist in it with remarkable constancy, and nearly in the same proportion under all circumstances. On analysis, it is found that 1000 grains of serum yield rather more than nine grains of saline matter: of these, about six and a half consist of muriate of soda, combined with a small quantity of muriate of potash, about one and a half of subcarbonate of soda, with a minute quantity of sulphate of potash, together with the phosphates of lime, iron, and magnesia. Sulphur is also present in it, as is proved by its tarnishing silver and blackening the acetate of lead. It is supposed that the saline matter contained in the serum of the blood stimulates the nerves of the heart, and thus contributes to the contraction of its muscular fibres; that it aids in the operations of the secreting organs; that it contributes to the process of digestion, and that it affords the materials of which the earthy portion of the bones is formed.

Of the Serosity of the Blood.

If, when, by the application of heat or of some chemical agent, the whole of the serum is coagulated into a solid mass, this mass be cut into small pieces and placed in the mouth of a funnel, a fluid drains from it which is called the serosity of the blood, or, if the mass be subjected to pressure, the same fluid may be obtained from it. The serosity, then, is the watery fluid obtained from the serum after its coagulation, and it is this fluid which is observed to issue from meat at table when cut into, as mutton and beef, and which is then called gravy.

Such are the individual substances which enter into the composition of the blood. All these substances, like those which constitute animal matter in general, are resolvable into the ultimate elements of carbon, oxygen, hydrogen, and azote. Tables are given in the works which treat of animal chemistry, showing the respective proportions in which these elements combine to form albumen, fibrin, jelly, and so on; but these need not be quoted here.

Thus it appears, from the preceding account, that the different appreciable and known constituents of the blood are the halitus; the crassamentum, which consists of fibrin and of red particles; the serum, which is composed of albumen, and of a watery fluid termed the serosity; and of various earthy and saline substances held in solution by the serum.

Of the Vital Properties of the Blood.

The blood not only maintains the life of all the other parts of the body, but it is itself alive. Some obscure notion of this kind prevailed at a very early period, and is alluded to by Hippocrates. Harvey formed a clearer conception of the truth, and Hunter states the fact distinctly, and in adducing the proofs of it which occurred to him, observes, that he had long suspected that life was not wholly confined to substances endowed with visible organization, and capable of spontaneous motion. Since the time of Hunter the opinion has been slowly but steadily extending among physiologists, and the evidence of its truth may now be considered as completely satisfactory.

1. There can be no evidence that a substance is alive but that it exhibits the phenomena which have been stated to be peculiar to, and therefore characteristic of, life. Whatever be, in other respects, the condition of a body which

exhibits truly vital phenomena, it must be admitted to be a living body. Now, the blood exhibits several of the most characteristic properties of life. In the first place, it is capable, like other living bodies, of resisting, within a wide range, the ordinary influence of physical agents. Many illustrations have already been given of the extraordinary power of the living body to resist intense degrees of heat and cold. Among these was mentioned, and we must again advert to it, on account of its striking analogy to certain phenomena exhibited by the blood, the preservative power of the egg. It is well known that the egg possesses the power of self-preservation for several weeks, although exposed to a degree of heat which would certainly occasion the putrefaction of dead animal matter. During the period of incubation the egg is kept at a heat of 103°, the hen's egg for three, that of the duck for four weeks: yet when the chick is hatched, the entire yolk is found perfectly sweet, and that part of the albumen, or white, which has not been expended in the nourishment of the young animal, is also quite fresh. It is found that if the preservative principle be destroyed, as it may be instantaneously, by passing the electric fluid through the egg, it becomes putrid in the same time as other dead animal matter.

Its power of resisting cold is proved to be equally great by several curious experiments of Hunter, which were so managed as to show, at the same time, both the power of the vital principle in resisting the physical agent and the influence of the physical agent in diminishing the energy of the vital principle. Thus he exposed an egg to the temperature of 17° and 15° of Fahrenheit: he found that it took about half an hour to freeze it. When thawed, and again exposed to a cold atmosphere, it was frozen in one half the time, and when only at the temperature of 25°. He then put a fresh egg, and one that had previously been frozen and again thawed, into a cold mixture at 15°: the dead egg was frozen twenty-five minutes sooner than the fresh. It is obvious that, in the one case, the undiminished vitality of the fresh egg enabled it to resist the low temperature for so long a period: in the other case, the diminished or destroyed vitality of the frozen egg occasioned it speedily to yield to the influence of the physical agent. Now precisely the same results were obtained in analogous experiments with the blood. On ascertaining the degree of cold and the length of time necessary to freeze blood immediately taken from the blood-vessel, he found that, as in the egg, a much shorter period and a much less degree of cold were requisite to freeze blood that had previously been frozen and again thawed, than blood recently taken from the vessel. It is reasonable to infer that this difference arises from the same principle; the vitality of the recent blood, being comparatively undiminished, enables it to resist the cold longer than blood the vital energy of which has already been partly exhausted by previous exposure to the influence of this physical agent.

2. Hunter adduces some facts to show that the blood, like other living substances, originates motion and action. We know that if a living egg be placed under a hen, or even exposed for a certain time to a degree of artificial heat equal to that in which it is maintained during incubation, certain motions or actions spontaneously arise within it which terminate in the development of the chick. This illustrious physiologist, from certain observations which he was the first to make, was led to the conclusion that an analogous process occasionally takes place in the blood. If in the living body blood be effused from its vessels, either upon the surfaces of organs or into cavities, it solidifies without losing its principle of life: it is not correct to say that the blood coagulates under such circumstances, for the term coagulation should be confined to the solidification of the blood without the body. If the solid thus produced be examined some time after its formation, it is found to abound with blood-vessels. Some of these vessels can be distinctly traced from the surrounding living parts into the solid: others cannot be traced from these parts. Those, the origin of which could not be found external to the solid, were supposed by Hunter to be formed within it. It is obvious that if this were really the fact, such a solid would commence an action which would terminate in its organization—an action perfectly analogous to that by which the incubated egg commences a series of movements which terminate in the development of the chick; an action which no substance could possibly originate unless it were endowed with life. It must be confessed, however that it is doubtful

whether the fact be correct, especially as thus stated. There is no doubt that the blood thus solidified within the body becomes organized. The point unsettled is, whether the vessels which organize it shoot into it from the living parts in contact with it, or originate, partly at least, within itself: the doubt, however, does not interfere with the present argument: a dead substance, thus surrounded by living parts, does not become organized; the blood does, and the argument is that, therefore, it must itself possess vitality.

3. An argument in favour of the vitality of the blood more conclusive, because the fact upon which it is founded is unquestioned and unquestionable, is derived from its fluidity. We know that, while circulating within its vessels, it is maintained in a fluid state. It could not circulate, it could not readily divide itself so as to permeate through the constantly diminishing tubes of the arteries, and the minute branches of the veins, unless it were fluid. All the actions of the economy would instantly cease, all the wheels of the machinery would be clogged and stopped, were the mass in the living body to become solid, or even to approach to the solid state. And yet its power of becoming solid is a property so essential to it, that without it all its other properties would be useless, because it is upon this power that the construction of the solid textures entirely depends. We have seen that its tendency to assume a solid state is so great that, when removed from the living vessel, a large portion of it is converted into a firm solid in a few minutes; and that, even within its vessel, if any circumstance happen to interrupt the circulation for a considerable time, it is exceedingly apt to become solid, and to plug up the channel. It is probable that slow motion increases its consistence in an appreciable degree: it is certain that absolute rest greatly promotes and hastens its solidification. Some of the most important and essential actions in the economy appear to depend upon this property, for the arrangement of the secerning vessels in all the organs of secretion is uniformly and strikingly such as to ensure an exceedingly slow motion of the blood through them. It was necessary, then, in constructing the blood, to preserve the balance between its fluidity and solidity so nicely, that, while all the purposes of the economy should be secured, its actions should not be impeded by the very instrument that was essential to them. A fluid must be formed capable of becoming solid with ease and certainty; and at the same time capable of maintaining its fluidity with the like ease and certainty. Now, a substance endowed with properties so opposite, and whose continuity of properties is so constantly called into play, and is so essential to the ultimate purpose of its action, is found in nothing purely mechanical: human ingenuity can construct no machinery analogous to it: it is found only in the mechanism of life, and the property is so peculiar to life, and so distinctive of it, that we have no other resource than to refer all the particular facts of this kind that are met with to the principle of life, and to say that they depend upon a vital principle. We cannot avoid some such modes of expression, and in fact this is the language uniformly employed by all physiologists. When they observe that the blood while it circulates in the living vessel maintains its fluidity, but becomes solid almost immediately after it is withdrawn from the vessel; when they observe that it is not the cessation of its circulation that causes its solidification, since, on making the experiment, they find that if it be kept at the same temperature as in the living body, and made to circulate with equal rapidity through a dead tube, it equally becomes a solid, they say it is maintained in a fluid state by the principle of life. We ought, however, never to forget that all expressions of this kind amount to no more than the general statement of the fact that the phenomena in question are uniformly found in connexion with the condition of life; and still less ought such language to divert our attention from, or render us insensible to, the beauty and wisdom of adjustments which, perhaps, we do not perceive to be mechanism only because the mechanism so much surpasses in delicacy and perfection any with which our gross senses have made us acquainted.

4. The blood must be a living substance because it is capable of dying. It is capable of sudden death; for if the electric fluid be passed through it, it is killed instantaneously, as has been stated already in a former part of this treatise. But it may be said to undergo the process of natural death, a process which has already been described under the name of coagulation. When this process is attentively examined it will be found to

be a very curious operation, bearing little analogy to any other with which we are acquainted, and the cause of which there is considerable difficulty in assigning. Perhaps the process which bears the greatest resemblance to it is the coagulation of albumen; but there is this essential difference between the two,—that albumen does not coagulate of itself, but only on the application of heat or of some chemical re-agent; whereas the blood coagulates spontaneously. Little light is thrown on the subject by considering the different circumstances in which the blood is placed when contained within its vessel and when withdrawn from it. In the one case, it is in constant motion, in the other it is in a state of rest: in the one case it is excluded from the air, in the other it is exposed to it: in the one case it is maintained in an equal and somewhat high temperature, in the other it is placed in a temperature considerably lower. Accordingly, rest and exposure to the atmospheric air and to cold have been assigned as the causes of the coagulation of the blood.

But that rest alone is not sufficient to cause the coagulation of the blood, is evident, on the one hand, because one of the most common methods of obtaining a coagulum is by constantly stirring the blood as it flows from a vein; and, on the other, because when a tourniquet is applied to a vessel the blood contained in it remains fluid: moreover in fainting fits, however long continued, in which the circulation appears to be stopped, coagulation does not take place.

That exposure to atmospheric air is not essential to coagulation is equally certain; for Mr. Hunter proved that coagulation takes places *in vacuo;* and we have seen that it occurs in situations from which the air must necessarily be excluded; in living vessels, in various cavities of the body, and on its surface: thus, when a blow has been received on the eye, causing the appearance which is termed ecchymosis, if, in about half an hour after the blow has been received, a lancet be plunged into the wound, the blood will be found coagulated.

Neither is cold necessary to the process. The temperature of the fish is about 60°: if the blood of the fish be removed from the body, and brought into a temperature of about 70°, it immediately coagulates. If blood, taken from a warm-blooded animal, as the rabbit, be frozen, and afterwards thawed, it will be found to be perfectly fluid. Numerous experiments show that the blood most readily coagulates at its natural temperature (98°); that it coagulates most slowly between 60° and 90°; and that below 38° and 32° it does not coagulate at all, but remains fluid. While it is evident, therefore, that neither rest, nor exposure to atmospheric air, nor cold, are essential to this curious process, yet all observation and experiment agree in showing that each promotes it in a considerable degree.

These observations abundantly attest how little the process of coagulation is dependent on physical agents: there are other phenomena connected with it, which show how closely it is related to the actions of life—phenomena which prove that the vitality of the blood increases or diminishes with the vitality of other parts of the body. The blood, when drawn from its vessel, does not instantly die or coagulate. By observing the length of time consumed in the process, we are able, in some sort, to measure the degree of vital energy it possessed. It is found that in diseases which depend on a preternatural energy of vital action, as in inflammation, the blood coagulates much more slowly than in a state of health, while the coagulation itself is more perfect; and, on the contrary, that in diseases which depend on a diminution of the vital energy, as in certain fevers, it either coagulates much more rapidly, or does not coagulate at all: because, in the first case, it possesses the vital principle in a higher degree than natural, and, therefore, resists longer the influence of the physical agents to which it is exposed; and, in the second case, it possesses the vital principle in a less degree than natural, and, therefore, sooner yields to the influence of those agents. A phenomenon connected with the coagulation of the blood, of great importance to the physician, depends on this principle: namely, the formation of what is termed the "buffy coat," an appearance in the blood which denotes inflammatory action in the system, and the presence of which affords an invaluable guide in the treatment of disease. The terms "buff" or "size" are employed to denote that state of the crassamentum when its upper part contains no red particles, but exhibits a layer of buff-coloured substance, lying on the top of the red clot. In this condition of the blood, the red particles

sink to the lower part of the clot before the coagulation is completed, and, therefore, the upper surface of the clot is colourless: at the same time, the whole of the coagulated portion is much firmer than natural. The red particles have time to subside before the coagulation is complete, because the coagulation is slower; and it is slower because, in the morbid condition of the system of which this buffy appearance is the sign, the blood possesses a higher degree of vitality than it does in a sound state. The truth of this opinion, which had long been prevalent among physiologists and physicians, is proved in the clearest manner by a very simple but beautiful series of experiments, instituted by Mr. Thackrah. These consist in receiving blood taken from the vessels of a living animal, in a full and uninterrupted flow, into different cups, and noting the time at which coagulation commences in each. For example, blood was taken from a horse at four periods, about a minute and a half being allowed to intervene between the filling of each cup. In the first cup coagulation began in eleven minutes, ten seconds: in the second cup, in ten minutes, four seconds: in the third cup, in nine minutes, thirty-five seconds: in the fourth cup, in three minutes, twenty seconds. In another experiment, blood was received from the vessels of a slaughtered ox into three cups—No. 1. being filled in the first flow; No. 2. about three minutes afterwards; No. 3. a short time before the death of the animal. Coagulation commenced in No. 1. in two minutes, thirty seconds: in No. 2. in one minute, thirty-five seconds: in No. 3. in one minute, ten seconds. In a similar experiment coagulation commenced in the first cup in two minutes, ten seconds: in the second in one minute, forty-five seconds: in the third, in thirty-five seconds. Similar phenomena are observed to take place in the human subject. Blood, to the amount of about one pint and a half, was taken from the arm of a woman labouring under fever: a portion of it received into a cup, on the first effusion, remained fluid seven minutes; a similar quantity, taken immediately before tying up the arm, was coagulated in three minutes, thirty seconds. Of blood taken, as in the preceding experiment, from the arm of a man, the first portion began to coagulate in seven minutes; the last in four. The vitality of the system, and, together with it, the vitality of the blood, being diminished by each successive abstraction, this fluid coagulated, that is, its vital principle become totally extinct sooner, and sooner in proportion as it was previously weakened.

Other experiments of Mr. Thackrah, perhaps still more interesting, go to establish, in the clearest manner, that vitality is communicated to the blood, or, at least, is maintained in it through the medium of the nervous system, the nervous influence being transmitted to it by the nerves of the vessels that contain it, the arteries and veins. Thus a portion of a vein, in a living animal, was included between two ligatures: this portion was allowed to remain in its natural situation: at the end of ten minutes the blood it contained was not coagulated. Again, a portion of a vein was included between two ligatures in a living dog: it was then removed from the body, and immersed in water at the temperature of 98°: the blood it contained was not coagulated at the end of an hour. On the other hand, a dog having been killed, a portion of a vein was immediately taken from its body and plunged into water, which was maintained for two days at the temperature of between 90° and 100°. At the end of this period a quantity of blood was made to flow from the vein of a living dog into this dead vein: the blood being secured by ligature in this dead vessel, was then immediately immersed in water, at the temperature of 98°: at the end of a quarter of an hour, the blood was found firmly coagulated. Thus, blood contained in a living vessel did not coagulate in the space of an hour: that inclosed in a lifeless vein coagulated in one-fourth of the time.

It has already been stated that coagulation, the process by which the blood is converted into a solid when abstracted from its vessels, is totally different from that by which it becomes solid, within the living vessel, or within the living system: that the first may be considered as its natural death; but that, on the second, depend some of the most important processes of the living economy. This may be illustrated very beautifully by attending to the process by which a wound heals. When a living solid is wounded, a number of its blood-vessels are divided; a quantity of blood is poured out into the cellular tissue that surrounds the wound; the red particles soon disappear, being taken up and removed by the absorbent vessels: an

adhesive matter remains which glues together the edges of the wound: this adhesive matter is the fibrin which gradually becomes organized: according to the received opinion, by the elongation of the minute blood-vessels of the immediate neighbourhood which shoot into the interior of the effused substance; according to Hunter, partly by this process, and partly by the origin of new arteries and veins which are formed within the effused substance, and which springing from it unite with the elongated vessels of the parts in the immediate neighbourhood: the effused adhesive matter, thus acquiring blood-vessels, and receiving a regular supply of blood, becomes a true and proper part of the living body, and exercises its appropriate functions in the economy. This process is called by surgeons, healing by adhesion: it depends essentially upon the solidification and adhesiveness of the fibrin, and without this property of the blood no loss of substance could be reproduced; no part of an injured organ could be repaired; no surgical operation could be performed; no wound in a blood-vessel could heal; and, consequently, the slightest cut must prove fatal.

Of the total Quantity of Blood in the Body.

The total quantity of blood in the body it is difficult to ascertain: the data on which the common calculations are made are uncertain—only approximations to the truth can be obtained. Haller estimates that, in the adult man, the blood may constitute about one-fifth part of the weight of the whole body. According to this calculation, a body weighing 150 pounds would contain about 30 pounds of blood: of this it is supposed that somewhat more than three-fourths are contained in the veins, and only one-fourth in the arteries. The quantity of blood in young animals is proportionably greater than in the old, or the adult, because, in the former, the body is not only to be sustained but enlarged, and many of the organs to be completed. In small and weak animals there is less in proportion to their size than in the larger and more muscular: in wild animals there is more than in the tame, and in the active more than in the sedentary. The quantity in different parts of the same animal is always in proportion to the importance of the organ: thus there is incomparably more in the brain and stomach than in the skin and bones.

Of the Circulation.

Having thus explained the formation of chyle from the aliment, and traced it to its conversion into true and proper blood in the lung; having described the several component parts of the blood, and given an account of the properties of each, we now proceed to the consideration of the mode in which this vital fluid is distributed to the different parts of the body. This brings us to the subject of the circulation, in treating which, in conformity to the plan of this treatise, we shall first of all consider the apparatus by which the function is performed, and afterwards the function itself.

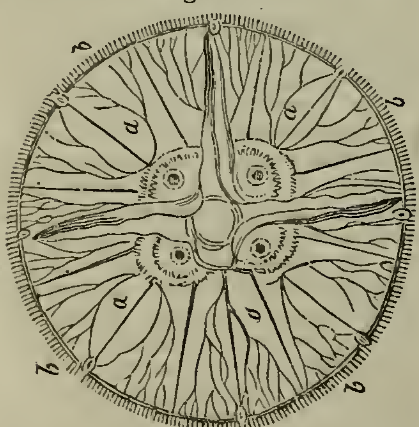
Of the Apparatus of the Circulation.

The circulation consists in the transmission of the nutritive fluid from a given point to the different parts of the body; and from the different parts of the body back to that point again. It is only when such a circle is performed that there is a true circulation. In order to carry on a circulation, a great number of organs is required, the possession of which is perfectly inconsistent with the simplicity of structure by which the lower classes of animals are distinguished. Wherever there is a true circulating system there is a complexity and perfection of organization, which gives to the creatures that possess it a high place in the animal scale: vast tribes of beings that occupy the lower part of the scale are destitute of every trace of it.

The necessity of a circulation exists only in animals of a certain structure. Whenever the nutritive fluid is elaborated in a special and isolated organ, there must be some means of conveying it from that organ to the other parts of the body: but where the entire body consists of one extended stomach there can, of course, be no need of a circulation. In almost all the orders of zoophytes the organization is thus simple. The infusoriæ, the polypes, the inhabitants of corals and sponges are composed of a uniform gelatinous substance, every part of which is constantly impregnated with its nutritive fluid, and is endowed with the power of supporting the changes, whatever they may be, that take place in their system. But we have seen that the earliest trace of a distinction of

parts in this uniform substance consists in the formation of a cell, a cavity, a tube, or some other special organization to which the performance of the function of digestion is restricted. Whenever this is the case, whenever the stomach assumes the form of a distinct organ, or begins to be in any degree isolated, then canals are seen to branch off from it in order to convey the nutritive fluid from this isolated spot to the different parts of the body. These canals usually branch off from the digestive organ in a radiated manner, because the figure of all these lower orders being more or less circular, the nutritive fluid is conveyed, by this arrangement, in the directest mode, to the extremities of the body. Hence, the earliest rudiment of a vascular system consists rather in the formation of an intestine than a vessel. These radiated canals are, at first, not distinct tubes composed of a peculiar tissue, but, as far as can be ascertained, appear to be merely excavations formed in the homogeneous substance of the body. Canals of this kind are first distinguishable in some of the higher orders of zoophytes. Thus, in the medusa there are seen to spring from the stomach distinct channels which proceed in a radiating manner towards the margin of the body, and which there empty themselves into a circular vessel (*fig.* 41); but it is impossible, in these animals, to distinguish any tubes for conveying the fluid back again to the organ whence it issued, and, consequently, they cannot be considered as possessing a true circulation. Even in animals the structure

Fig. 41.



Medusa amita seen from below; *a, a,* radiating vessels; *b, b, b, b,* circular vessel into which the radiating vessels empty themselves.

of which, in many important particulars, is considerably more advanced than that of the medusa, as intestinal worms, the rudiments of the vascular system present still more the appearance of ramifications of the intestinal canal.

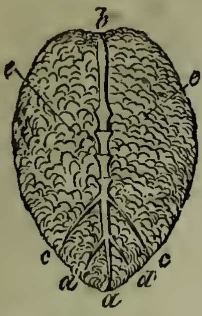
The first distinct and certain vessel for the distribution of the nutritive fluid appears to be found in the insect. If the general mass of the body, in almost all the orders of this class, be examined with a microscope, it will be impossible to detect the least appearance of a blood-vessel, although minute ramifications of the tubes, called tracheæ, are abundantly manifest in every part: but there is placed along the back a distinct tube, in which alternate dilatations and contractions may be clearly discerned. This tube is called the dorsal vessel. It constitutes a thin membranous canal of a uniform size: it is well seen in the caterpillar (*fig.* 42): but in this insect

Fig. 42.

A part of the dorsal vessel of the caterpillar, with the fine ramifications of the tracheæ attached to it.

this canal is closed at both extremities, and no trace of a vessel in communication with it, either going to it or coming from it, can be discerned. It is remarkable, however, that it is completely surrounded by exceedingly minute ramifications of the tracheal tubes (*fig.* 42). If this vessel be removed from the body, or if the fluid it contains be coagulated by muriatic acid, the animal will continue to live, and does not appear to suffer any material inconvenience from its loss or obstruction. In the higher orders of insects, as the spider and scorpion, this vessel is more developed. In some of the arachnidæ, as in those spiders which are not covered with hair, it can be seen to pulsate with the naked eye; and, on careful examination, several vessels can be perceived to be given off by it, many of which can be traced to the branchiæ, and others are lost in certain bodies, called adipose (*fig.* 43): but the actual distribution of these vessels, and the route which the fluid they contain pursues, cannot be discovered with any

Fig. 43.



a b, dorsal vessel of the spider; *c, d, c, d*, distinct branches given off from it; *e, e*, adipose bodies.

certainty, on account of the extreme delicacy of the vessels.

In a physiological view there is, at this point, a broad line of demarkation in the structure and functions of animals. On one side of this line, the lowest, are found all the orders of animals which are either altogether destitute of a vascular system, or in which there can be discovered only the faint and imperfect traces of it which have been described: and on the other all the orders of animals in which the vascular system is more developed; from those which possess a true circulation, however simple in form, to those in which the circulation is carried on in the most complicated and perfect manner. All the tribes of animals, on the one side, will be found to bear to each other a perfect physiological resemblance in the most important points of their organization, and to present to those, on the other side, equally important differences; these resemblances and differences being especially apparent in the essential functions of nutrition, respiration, and secretion.

The most simple form of a true circulation which is found actually to exist in the animal organization is that in which one set of vessels conveys the nutritive fluid to the different parts of the body, and from which another set of vessels, uniting with the first, returns the fluid to the point from which it originally set out. These two orders of vessels receive different names. The vessel which conveys the nutritive fluid to the different parts of the body is always called an artery: the vessel which returns the nutritive fluid from the different organs of the body, after it has circulated through them to the point whence it began to flow, is called a vein. The apparatus requisite for the circulation, therefore, in its primitive form is extremely simple: there are required only two sets of vessels directly communicating with each other. Even so low down as the echinodermata, the highest order of zoophytes, Cuvier thinks he has discovered an example of this mode of circulation. In the holothuria, he describes a set of vessels which carry out the nutritive fluid to the different parts of the body, and which he, therefore, conceives to be analogous to arteries; and another set of vessels communicating with the first which return the fluid, and which, therefore, perform the function of veins. It is certain that some genera among the mollusca possess a circulating system thus simple.

The next advancement in the organization of the vascular system is the construction of an organ which is usually placed between these two orders of vessels, and which, on account of its position, separating, and at the same time uniting, the two great systems of vessels, is called the central organ of the circulation. The name by which this organ is designated is the Heart. It is an engine placed between these two sets of tubes to assist in propelling the fluid they contain through them. It is a very important instrument in carrying on the circulation, but it is not essential to it, since a true circulation may exist without it: its presence, however, always implies a higher and more perfect, because a more extended and complicated, and, therefore, a more richly endowed organization. The first approach to the formation of such a central organ is observed in some of the more perfect orders of Vermes. In the *lumbricus terrestris*, or common earthworm, the communicating branches which run between the abdominal and dorsal vessels, exhibit several heart-shaped dilatations, which have been seen to contract with peculiar energy. In the crustacea these dilatations are more defined, and their action is more definite. The heart of the *astacus fluviatilis*, or cray-fish, is distinctly muscular, sends off several arteries both backwards and forwards, and when even wholly removed from the body, it may be observed to pulsate with very considerable activity. The state of the circulation, however, in all these orders of beings is very imperfectly understood; and the influence which a heart, so rudely constructed, can exert upon it cannot be estimated high.

Ascending another step in the scale of organization, we find it consisting of two bags or apartments which open into each other; between which there exists a free and constant intercourse. One of these apartments is destined to reoeive the blood from the vein; the other is intended to propel it into the artery. These two bags or apartments, like the two orders of vessels, receive appropriate names: that which receives the blood is always called an auricle; that which propels it forwards is always called a ventricle: from this account of their office it is obvious that the auricle must always be in communication with a vein, and the ventricle with an artery: the bag called the auricle always receives its fluid from a vein; the bag called the ventricle always propels its fluid into an artery.

The apparatus for the circulation, then, in an animal which possesses a simple heart, consists of a vein, of an auricle, of a ventricle, and of an artery; of a vein to convey the blood to the auricle; of an auricle to transmit the blood to the ventricle; of a ventricle to propel the blood into the artery; and of an artery to distribute the blood to all the parts of the body. The trunk of the artery when it springs from the ventricle, of course, is a large tube. If it perform its office perfectly, that is, if it convey the blood to all the parts of the body, to its most distant extremity, to its minutest portion, it must of necessity divide and subdivide, and subdivide again and again into branches of constantly decreasing magnitude, until at length they become exceedingly, we may almost say inconceivably, minute. When we consider that the finest point of the finest needle cannot pierce the vascular part of an animal without causing the blood to flow from the point pricked, we can have no difficulty in conceiving the extreme minuteness of the ultimate subdivisions of the vessel. These minute and ultimate subdivisions of the artery are called its capillary branches. The artery, then, may be said to arise from the ventricle of the heart by one large trunk, and to terminate in the organs by capillary branches. The vein divides and subdivides, in a similar manner, into branches equally minute, into capillary branches; but the course of the capillary veins is the reverse of the course of the capillary arterial branches. As the artery arises from the heart and terminates in the organs, so the vein arises in the organs and terminates in the heart. Where the capillary branches of the artery terminate, there the capillary branches of the vein begin, and precisely there the two sets of vessels unite. Thus the capillary branches of the artery terminate in the organs by opening into the capillary branches of the veins. And thus we see how, by the course and communication of the tubes, the fluid they contain in moving through them must describe a perfect circle. In *fig.* 44 we see a plan

Fig. 44.

e, trunk of the vein; *a*, the auricle; *b*, the ventricle; *d*, the trunk of the artery; *e*, capillary branches of artery and vein united.

of the circulatory apparatus as now described: *c* represents the vein, *a* the auricle, *b* the ventricle, *d* the artery, *e* the capillary branches of the artery and vein united. The points of the darts are in the direction of the current of the blood as it flows through the vessels. Let us trace that current from the points of union of the capillary vessels, in *e*. The capillary branches of the vein receiving the blood from the capillary branches of the artery convey it to the trunk of the vein, *c*; the vein transmits it to the auricle, *a*; the auricle sends it on to the ventricle, *b*; the ventricle propels it into the trunk of the artery, *d*, which by its capillary branches reconveys it into the capillary branches of the vein, and so the circle is complete.

Such is the circulation with a heart constructed on one of the most simple models: and such is the actual course of the circulation in a large olass of animals, as in the mollusca. In this class the heart is said to be simple, and the circulation single: single because it describes only one complete circle.

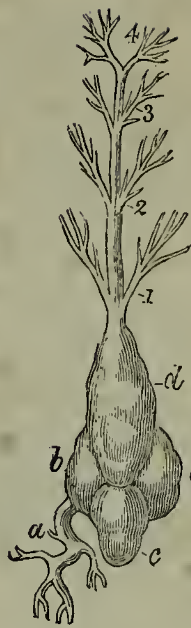
Merely for the purpose of conveying the nutritive fluid to all the parts of the

body, and of keeping up a constant circulation of it through all the organs, the apparatus that has been described is sufficient. But the nutritive fluid, in describing this circle and in nourishing the organs on which it is spent, becomes deteriorated or deprived of its nutritive property. It is necessary for its renovation that it should be brought into contact with atmospheric air. For this purpose a new organ, which is called branchiæ or gills in the lower, and lungs in the higher orders of animals, is required, and consequently the apparatus of the circulation must be complicated by an additional instrument for conveying the blood to the branchiæ or to the lungs: hence arises the next complication in the structure of the heart or of the circulating apparatus.

The expedient by which this necessary purification of the blood is accomplished is by the communication of an additional artery to the apparatus, an artery which is made to convey the blood directly from the heart to the branchiæ, or lungs, and which, on account of its office, is called the pulmonary artery. The apparatus now consists of one vein, one auricle, one ventricle, and two arteries; namely, the pulmonary artery, and the primitive artery, which, in order to distinguish it from this new vessel, now takes the name of aorta. It is obvious that the pulmonary artery must always be placed between the heart and the organs of respiration, while the aorta must be placed between the organ of respiration and the general system of the body in order to receive the renovated blood from the respiratory organs, and to carry it out to the system. The structure of the apparatus of the circulation in the fish will illustrate this arrangement very beautifully.

In the fish (*fig.* 45) there is, first, the vein *a*, which conveys the blood to the heart; secondly, the auricle *b*, which receives the blood from the vein; thirdly, the ventricle *c*, which receives the blood from the auricle; and fourthly, *d*, a large artery which springs from the ventricle. Hitherto, then, the apparatus is precisely the same as that which has been already described as affording an example of it in its most simple form; but in that form this artery would convey the blood to the system. In the fish, on the contrary, it conveys it not to the system, but to the branchiæ, or the organs of respiration: it is, therefore, the pulmonary artery. From the

Fig. 45



Heart of the Fish. *a*, the vein which returns the blood from the different parts of the body to the heart; *b*, the auricle into which the vein opens; *c*, the ventricle; *d*, the large blood-vessel arising from the ventricle; 1, 2, 3, 4, its branches, which go to the branchiæ.

branchiæ the blood passes into a large artery, which is the analogous artery of the most simple model, because it is by its branches that the blood is conveyed to the body of the animal: this artery, therefore, is the aorta, or the systemic artery. The capillary branches of the aorta unite in the organs with the capillary branches of the vein, while the latter reconvey the blood back to the auricle of the heart; and thus, in the fish, the circle is complete.

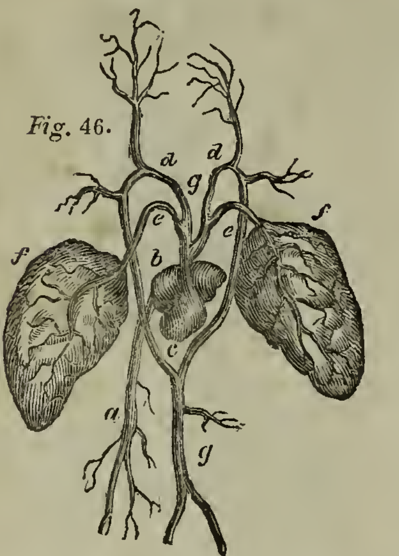
In fishes, the size of the heart is exceedingly small in proportion to the bulk of the body. According to Tiedeman, it is but the $\frac{1}{351}$th or $\frac{1}{768}$th of the weight of the body, while in man it is $\frac{1}{160}$. The proportion of blood possessed by fishes is very small: they have, comparatively, few blood vessels, and even of these they have a small proportion of red and a much greater number of colourless vessels: hence their muscles are pallid, or white, and present a complete contrast to the deep red colour of the muscles in the higher animals.

In the next order of animals, that of reptiles, there is a peculiar modification of the pulmonic portion of the circulating apparatus: indeed, all the modification of this apparatus, from its most simple

to its most complicated model, has relation to the pulmonic portion, and arises out of the necessity of adapting the heart and its appendages to the peculiar mode in which the animal respires. Of this we shall perceive additional proof at every step of our subsequent progress.

In the frog (*fig.* 46) the heart consists of

Fig. 46.



Heart of the Frog. *a*, the vein; *b*, the auricle; *c*, the ventricle; *g*, the great artery, dividing into *e e*, the pulmonic artery; and *d d d*, the aorta; *f*, the lung.

the same parts as those which have been described as constituting the circulatory apparatus of the fish. It has the same vein, *a*; the same auricle, *b*; the same ventricle, *c*; the same artery, *g*; but in the fish, this artery passes directly to the branchiæ: were the arrangement, therefore, perfectly similar in these animals, this artery would, in the frog, proceed immediately to the lung, *f*. Instead of this, however, it divides into two great branches, of which one, *e*, goes immediately to the lung, *f*, while the main trunk, *d*, passes on to the body. In this case, then, the branch *e* is the pulmonic artery, and the branch *d* is the aorta or the systemic artery. On inspecting this plan of the frog's heart, which is the model of that on which the heart of all amphibious creatures is constructed, it is obvious that only one half of the blood received from the ventricle is transmitted to the lungs before it is conveyed to the general system. Hence in these creatures only one half of the blood is aërated, and that which circulates in their general system is always one half venous and one half arterial. The general constitution of all the creatures of this class is distinguished by very striking peculiarities. They are sluggish, languid, cold, inert, difficultly moved, and tenacious of life to a wonderful degree. They can bear all kinds of stimuli: they can bear to have their hands, legs, bowels cut away. Among other peculiarities of their constitution, they can live long without air: they will rise from time to time above water, if you will allow them: they can bear, again, to be kept under water, if you force them; but if they can live long under water, they can also live at least as long after you have cut off their heads or cut out their hearts."* As will be fully explained when we treat of the function of respiration, all these peculiarities are referable to the imperfect degree in which the blood is aërated; although in some of the higher orders of this class more blood is exposed to the air than in the frog, yet in a physiological view the structure of the circulatory apparatus is essentially the same in all. The heart in all these animals, though somewhat larger than in fishes, is still much smaller than in the higher classes: the weight of the heart in the frog is the $\frac{1}{246}$th part of the weight of the body.

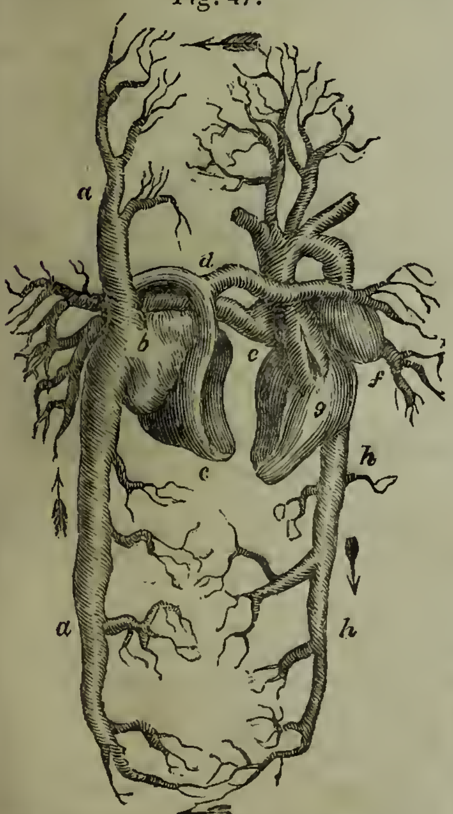
In the next class, that of birds, there is a prodigious advancement in the organization in general; and, in the circulatory and respiratory apparatus in particular. In the frog the lungs are small, and only one-half of the blood of the body passes through this little pulmonary system: hence the cold-bloodedness and inertness of the creature. In the bird, on the contrary, besides the proper lungs, there are additional bags for the extension of their respiratory system, and even all the great bones of its body are hollow and filled with air, and made subservient to the aëration of the blood: instead, therefore, of being cold-blooded like the reptile, the temperature of the bird is higher than that of any other animal; and, instead of being sluggish and inert, it is, of all creatures, the most quick and active. It will be readily conceived that the apparatus for the circulation must be essentially different in a creature which possesses a respiration, and a general constitution so strikingly contrasted to that of all the

* Bell's Anatomy, vol. i. p. 475.

classes below it. Accordingly, in the bird, the heart is no longer simple, it is highly complicated—as complicated as it is in the mammalia and in man: it is properly double: indeed, there is no physiological difference between its structure and that of the most perfectly organized animal: it has some peculiarities which are strictly connected with the peculiarities of its lungs, but these will be better understood when we treat of the apparatus of respiration. As we have now arrived at the most perfect model of the heart, and as its structure is in strict conformity to this model in all the ascending scale, instead of describing it as it is found in the bird, and in the mammalia, we shall describe it as it exists in man.

In man, and in all the higher animals, the heart is double; one heart is for the circulation through the lungs, the pulmonic: the other for the circulation through the body, the systemic. In (*fig.* 47) is given a plan of the heart,

Fig. 47.



as constructed on this model, and for the sake of making the arrangement more intelligible, the two hearts are represented in this figure as placed at some distance from each other: *a*, *a* represent the vein: it is now convenient to give this vein a name: on account of its great size in man, and in the higher animals, it is called the *vena cava.* There are, it will be seen, two veins, one above, and the other below: the one above brings the blood from the head and the superior extremities; it is called the superior *vena cava:* the one below brings the blood from all the lower parts of the body: it is named the inferior *vena cava.* The two *venæ cavæ* meet at *b*, and pour their blood into the auricle *b*, which must now be distinguished by the term *right.* The right auricle is partly formed by the dilatation of these veins; but there is, also, a portion of it which is strong and muscular, and which is commonly described as forming the proper auricle. The *right auricle* opens into *c*, the *right ventricle*, which is larger than the auricle, and possesses much thicker and stronger muscular walls. From the right ventricle springs the *pulmonic artery*, *d*, which divides into two large branches, one of which goes to the right lung, and the other to the left. This, then, is the apparatus for the right side of the heart, for the pulmonic or the lesser circulation: all this part of the apparatus merely performs the office of conveying the blood to the lung, in order that it may be aërated or renovated in that organ. The capillary branches of the pulmonary artery, after ramifying through the lungs, at length unite together, and form four veins, two from each lung: they are well seen in *fig.* 53, and are marked *c, c; c, c;* these are called the *pulmonary veins.* The pulmonary veins transport the blood to the left heart, which consists of exactly the same number of parts as the right; namely, of these veins, which are represented in *fig.* 47 by the letter *e*; of an auricle *f*; a ventricle *g*; and a large artery *h h*. The *left auricle, f*, receives the blood now purified from the lungs; conveys it to the *left ventricle*, *g*, which propels it into the great artery, *h*, the latter being, as we now know, the aorta or the systemic artery. In this case, then, there are completed two perfect circles, by precisely corresponding instruments: one of these circles, the pulmonic, is through the lungs; the other, the aortic or systemic, is through the body: one of these circles commences in the capillary veins of the body, or the systemic veins,

and terminates in the capillary branches of the pulmonary artery, in the lungs: the other circle commences in the capillary branches of the pulmonary veins, and terminates in the capillary branches of the aorta; and since the capillary branches of the aorta open into and unite with the capillary branches of the systemic veins, it is obvious that this double course forms and completes one grand circle.

We have stated that, in order to render this description more intelligible, we have supposed these two hearts to be placed at some distance from each other. Had they been placed in opposite sides of the chest, it is clear that they might have carried on the circulation: but important advantages may result from the union; important advantages must result from their union, and, accordingly, they are united. The fibres of the two hearts intermix, and thus mutually strengthen each other; and both are enclosed in one and the same membranous capsule; namely, the pericardium: but though they are united, and acquire additional power by their union yet the action of their different parts is precisely the same as they would have been had the right heart been placed in one part of the body, and the left in another. Thus the systemic and the pulmonic veins, the right and the left auricle, the right and the left ventricle, the pulmonic and the systemic arteries, correspond to each other in time and action, and perform their appropriate function in the most perfect and beautiful accord and harmony.

Fig. 48 represents the plan of a heart, constructed on this united and perfect model, and exhibits it such as it actually exists in the human subject. Thus, *a, a*, represent the two *venæ cavæ*; *b, b*, the right and left auricles; *c, c*, the right and left ventricles; *e e*, the pulmonary artery, and *d, d*, the aorta. The pulmonary veins, being placed behind, can be seen only in a posterior view of the heart: they are represented in *fig.* 53, and marked by the letters, *c c, c c*.

In man, the apparatus of respiration consists of the lungs, and these occupy the cavity of the chest (*fig.* 75). The chest is divided into two portions, a right and a left portion, in each of which is placed one lung (*fig.* 75 *b, b*); hence there are two lungs, a right and a left, which have no communication with each other except by vessels. The heart is

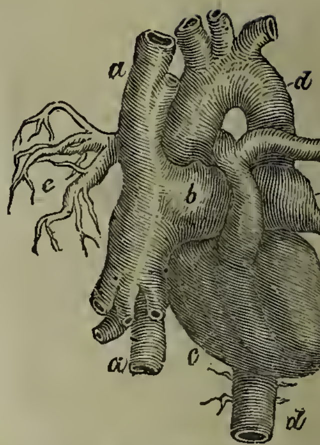


Fig. 48.

Double Heart, united. *a a*, the two venæ cavæ (superior and inferior); *b b*, the two auricles (right and left); *c c*, the two ventricles (right and left); *e e*, the pulmonary artery, with its division into right and left branches; *d d*, the aorta.

placed in the left side of the chest, in contact with the left lung, towards its middle and lower part (*fig.* 75, *a*.) Its direction (*fig.* 49) is oblique: its broad

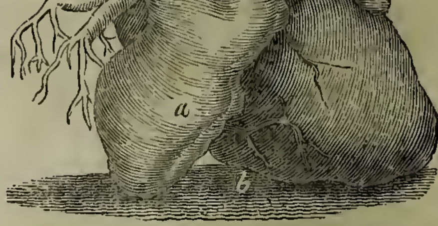


Fig. 49.

Position of the Heart, showing its oblique direction. *a a*, the venæ cavæ, distended; *b*, points to the situation of the basis of the heart; *c*, apex of the heart; *d*. the aorta.

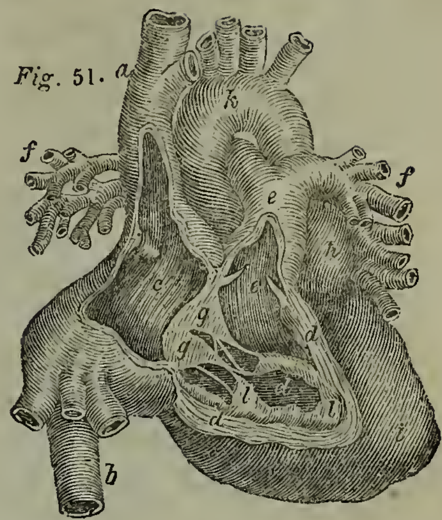
part or basis is placed upwards, backwards, and to the right side: its apex is placed downwards, proceeds to the left, where its pulsation may be felt, corresponding to the fifth and sixth ribs.

The heart is held in its situation by a membranous bag which encloses it, and which is termed the pericardium. This bag is attached to the large vessels which spring from the heart a little above its basis (*fig.* 50): but no opening is formed

Fig. 50.

a a a a, margin of the pericardium, which is here represented as cut open.

Fig. 51.



Right side of the heart, or pulmonic portion. *a*, superior vena cava; *b*, inferior vena cava; *c*, right auricle, opened; *g g*, the valve occupying the opening leading from the right auricle into *d*, the right ventricle; *d d*, the cut edges of the right ventricle, showing the thickness of its muscular wall; *e e*, the pulmonary artery, arising from the right auricle, and dividing into two large branches *f*, *f*, which go to the right and left lung.

in the pericardium, for the outlet of the vessels. The vessels do not properly perforate the membrane; but the membrane is what anatomists call reflected upon them: that is, the inner layer of the pericardium is laid upon the external surface of the vessels, united closely with that surface, and insensibly lost upon it. This arrangement is extremely curious and beautiful: it constitutes the pericardium a closed bag, while, at the same time, it allows of the exit of these vessels.

The size of the pericardium is always in proportion to the magnitude of the heart. While this membranous bag fixes the organ firmly in its situation, it is as much larger than the heart as may be necessary to admit of its freest action; it sits loosely and easily about it, guarding its substance without confining its movements: it contains about a spoonful or two of limpid fluid, just sufficient to keep the surface of the heart in a state of suppleness and moisture. The action of the heart is essential to life, and must be incessant; and, therefore, the most extreme care is taken to afford it a free space to act in, and to guard that space from invasion.

By looking at *fig.* 51, it will be seen that the right auricle (*fig.* 51, *c*) is situated at the basis of the right ventricle: it is here partly opened: at its upper and back part is the opening of the *vena cava superior*, *a*, which, as we have seen, returns the blood from the head, neck, and upper part of the body: opposite to it is the opening of the *vena cava inferior*, *b*, which returns the blood from all the lower parts of the body.

From the right auricle a large opening leads into the right ventricle, termed the *auricular orifice of the ventricle:* its situation is marked, and is occupied by the valve, *g*, *g*.

The right ventricle is much more thick and muscular than the auricle; there is spread over its internal surface an irregular net-work of fibres, some of which are marked by the letters *l*, *l*, *l*. Many of these fibres are fixed by one extremity to the sides of the ventricle, while the others terminate in tendinous threads which are attached to the membrane forming the valve *g*, *g*, placed around the auricular orifice: to this membranous valve attention will be drawn immediately.

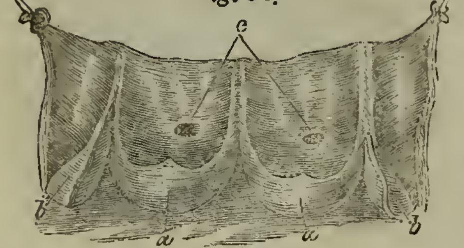
From the upper and left side of the right ventricle springs the pulmonic artery *e*, *e*, at the entrance of which are placed three membranes of a crescent or semilunar shape, termed the three semilunar valves: their situation is marked by the letter *e*, and their form is well

seen in *fig*. 52, which shows two of the semilunar valves of the aorta entire.

The structure of the left side of the heart is so similar to that of the right, and the action resulting from that structure so analogous, that a few words only will be necessary to complete the description of the circulatory apparatus.

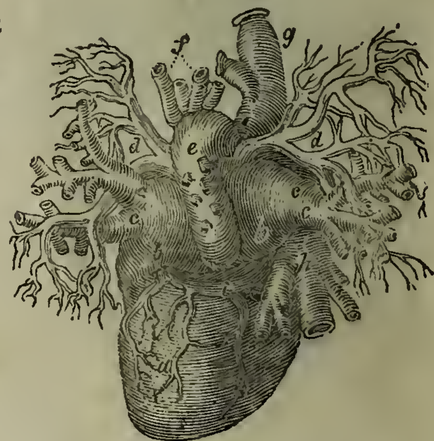
The left auricle, the external figure of which is best seen in a posterior view of it, as in *fig*. 53, *b*, *b*, is furnished in the interior with muscular fasciculi, similar to those of the right. In its upper and back part (*fig*. 54, *f*) are found four openings, which are the mouths of four veins, two from the right, and two

Fig. 52.



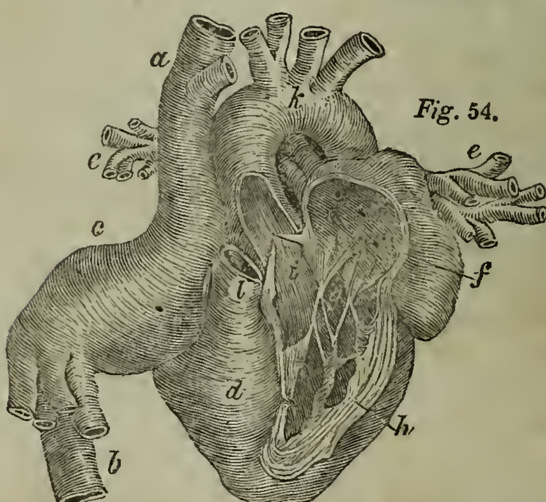
a, *a*, two of the semilunar valves of the aorta; *b*, *b*, the third divided; *c*, the coronary arteries.

Fig. 53.



Represents a posterior view of the Heart. *a*, the left ventricle; *b b*, the left auricle; *c c c c* the four pulmonary veins; *d d*, the two great branches of the pulmonary artery; *e*, the aorta; *g*, the superior vena cava; *h*, the inferior vena cava; *f*, branches given off from the aorta.

Fig. 54.



a, superior vena cava; *b*, inferior vena cava; *c*, right auricle; *d*, right ventricle; *k*, the trunk of the pulmonary artery cut off and removed, in order that the other parts shown by the figure may be seen distinctly; *e e*, point to the direction of its right and left branches; *f*, left auricle, pointing to the opening of the four pulmonary veins, two from the right and two from the left lung; *g*, the valve placed at the opening between the left auricle and the left ventricle, connected by tendinous cords with the fleshy columns which are seen arising from the wall of the ventricle; *h*, thickness of the wall of the ventricle; *i*, commencement of the aorta, springing from the left ventricle; *k*, the arch of the aorta, with the great branches given off from it.

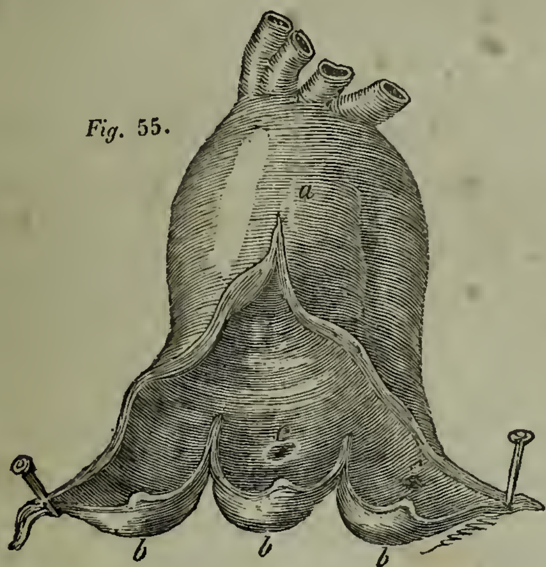
from the left lung, termed, therefore, pulmonic: these veins are seen in *fig*. 53, and are marked *c*, *c*, *c*, *c*.

Between the left auricle and the left ventricle a valve is placed, corresponding to the valve on the right side (*fig*

54, *g.*) The parietes of the left ventricle are nearly as thick again as those of the right (*fig.* 54, *h.*) From its upper and back part springs the great artery which conveys the blood to every part of the body, the aorta (*fig.* 54, *k.*) Around the commencement of the aorta are placed three semilunar valves (*fig.* 55, *b*, *b*, *b*), similar to those at the mouth of the pulmonary artery.

The heart itself is composed of four distinct tissues: first, of a layer of the pericardium, which, being reflected, forms its external surface · secondly, of

Fig. 55.



Represents the aorta slit open towards its arch, *a*, in order to show entire the three similunar valves, *b b b*, placed at its mouth; *c c*, the coronary arteries.

a fine transparent membrane, which lines the whole of its internal surface; thirdly, of muscular substance, which is included between these two membranes; and, fourthly, of cellular tissue, which surrounds and invests the muscular fibres; and which, on account of the elasticity which, it has already been shown, is the distinctive property of this tissue, is absolutely essential to the action of the organ. Though the cellular tissue, as it is mixed up with the muscular fibre of the heart, is extremely delicate, yet it endows the heart with such an eminent degree of elasticity, that if a portion of the ventricle be cut and stretched, it regains its original bulk and figure the instant the distending power is removed. The necessity and the beauty of this structure will abundantly appear when we treat of the heart's action.

Such is the structure of the apparatus for the circulation*; but it is still necessary to add a few words relative to the structure and distribution of the vessels which carry out and return the blood, before the function can be understood.

The vessels which are essential to the apparatus of the circulation, consist of three distinct orders, namely,—1. the arteries; 2. the veins; and 3. the lymphatics. The different function performed by the arteries and the veins has already been stated; the lymphatics, which may be considered as appendages to the veins, although they do not convey blood, but chyle and lymph, are an essential part of the circulating system, because they transport to the former vessels the fluids which supply them, and they communicate directly with both orders, obviously with the veins, and so readily even with the arteries, that injections will pass from the arteries into the lymphatics.

Arteries and veins possess three coats, the lymphatics only two. Of these the external is called the cellular coat. It consists of small whitish fibres which are

* Those who wish for a more detailed account of the structure of this apparatus than it was possible to give in this place, are referred to the valuable work of Messrs. John and Charles Bell, on the Anatomy and Physiology of the Human Body, from which several of the figures illustrating this Treatise have been taken, viz. figs. 47, 48, 49, 50, &c.

very dense and tough, and which interlace together in every direction. It is proportionably thicker in the larger than in the smaller arteries, and it gives to the vessel its chief strength. Its most important property is its elasticity, with which it is endowed in a very high degree. The second is termed the middle or the fibrous coat. It consists of fibres of a yellowish colour, which pass in a circular direction around the calibre of the artery, forming not complete circles, but segments, which, uniting, produce rings. These fibres are disposed in several successive layers, which can be readily peeled off one after the other, and which form altogether a pretty thick tunic. It is thicker in the small branches than in the large trunks, the reverse of what is found in the cellular coat. While it is firm and elastic it is extremely brittle; but by far its most important property is its contractility, with which vital property it is eminently endowed, and the exercise of which is essential to the function of the vessel. Since in man and the higher animals the property of contractility is confined to the muscular fibre, this fibrous coat has been supposed to be of a muscular nature; but it is so different in its aspect from the muscular fibre, that its muscularity has been vehemently denied by some of the most distinguished anatomists and physiologists: it may be, however, and it probably is, a modification of the muscular fibre. The third or internal coat consists of thin, dense, whitish, and almost transparent fibres, which are smooth and polished in their aspect; and the whole surface of the tunic is moistened with a thin and somewhat unctuous fluid. In many parts the membrane is formed into folds of a semilunar shape, which are termed valves, and which are disposed in such a manner, that they allow a free passage to the blood in the course required by the circulation, but effectually prevent the retrograde direction of the current. This tunic, though thin, is so firm and strong, that after the other coats have been entirely removed in a living animal, it is capable of resisting the impetus of the blood, and of preventing the dilatation of the artery; it is smooth and polished, to afford as little friction as possible to the blood, and firm and strong, to prevent its escape.

All these vessels are themselves abundantly supplied with vessels termed the *vasa vasorum*, by which they are nourished, and which are essential to their life and action. Each individual part of an artery is furnished with its own appropriate vessels, and when it is necessary in surgical operations to tie the trunk of an artery, it is found that the utmost care must be taken to disturb it as little as possible, exposing just as much of it as is absolutely required for the application of the ligature; for if it be detached from its situation to any extent, its natural vessels are ruptured, and so its supply of nourishment is cut off, whence it becomes diseased, and ultimately dies, or in surgical language it ulcerates and sloughs, and the consequence often is fatal hæmorrhage.

In like manner all these vessels are abundantly supplied with nerves, which, in the artery, appear to be distributed principally to the fibrous coat, and to endow it with a peculiar sensibility—a sensibility which causes it to receive a peculiar impression on the contact of the blood—an impression which excites it to contraction, the blood thus forming its appropriate stimulus.

From what has been said of the vascular system, it is evident that the vessels which compose it are highly important organs; that no injury can be inflicted on them without producing serious mischief, and that any considerable violence applied to them must necessarily be attended with a fatal result. On this account the greatest possible care has been taken to protect them, by placing them in situations in which external force can scarcely reach them. These great trunks are uniformly situated in the cavities of the body, or are embedded deep in the substance of the limbs: they pursue their course in the neighbourhood of the bones, and under their shelter; often in grooves excavated in the bones, on purpose to receive and secure them. Whenever they approach the surface, they divide into small branches, and this division goes on diminishing the calibre of the vessels, until when actually at the surface they are exceedingly minute. A wound in an artery being much more dangerous than a wound in a vein, on account of the greater impetus with which the blood is propelled through the former, the artery always lies deeper than the vein, and is more embedded in soft and elastic substances, and more concealed in channels formed in the bones, or protected by stout parapets thrown up on each side of it.

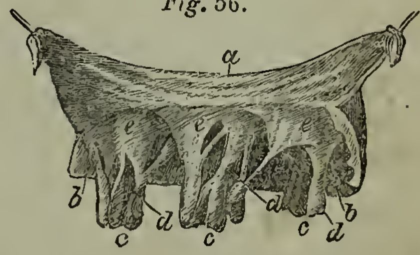
As it is indispensable to the maintenance of health, and often to the preservation of life, that every organ should receive a due supply of blood, two expedients are adopted to guard against an interruption to the circulation in any part. In the first place, every organ receives a supply from more than one source, and by more than one arterial trunk; all the important organs form several: the brain, for example, receives four exceedingly large trunks from four distinct and independent sources; and in the second place, all the branches unite together so intimately, that if the blood find the slightest check in one branch, it instantly finds an open channel in another. Perhaps in the whole compass of animated nature no sight is more beautiful than the inspection of the transparent part of a living animal by means of a microscope: the intersection and mingling of the different vascular branches, through all of which the particles of the blood find the readiest conceivable access, forms not only a most curious but most wonderful object. This union, or, as anatomists term it, inosculation of vessels, is capable of being increased to an astonishing extent in particular states of the system. If, from any cause, a large branch of an artery be obstructed, the other branches which it gives off are capable of enlarging sufficiently to carry on the circulation without impediment; and even if the main trunk be obliterated, the collateral branches will perform its function so perfectly as to prevent the system from sustaining any material injury. Guided by the knowledge of this principle, modern surgeons daily undertake operations, the idea of which would have filled with terror the surgeons of former days. Trunks of arteries are taken up of amazing size, and in situations where one would have thought it must be certain death for the needle of the surgeon to penetrate. If the reader will cast his eye on any map of the arteries, he will be struck with the force of this observation, when it is stated that these splendid achievements of modern surgery were accomplished in the following order:—First, the operator ventured to take up the femoral artery; then the external iliac; then the subclavian artery below the clavicle; then the common carotid; then the subclavian artery above the clavicle; then the internal iliac; then the arteria innominata; and lastly, even the abdominal aorta itself. By these difficult and stupendous operations, diseases which appear to be far beyond the reach of all human aid, and which without aid proceed with a sure and rapid pace to a fatal termination, are arrested.

Course of the Blood in Man.

The blood is returned from all parts of the body into the right auricle by the superior and inferior vena cava. From the right auricle it is propelled into the right ventricle. From the right ventricle it is conveyed by the pulmonic artery into the lungs. From the lungs it is returned by the four pulmonic veins into the left auricle. From the left auricle it is propelled into the left ventricle, and thence it is conveyed to every part of the body by means of the aorta.

But in pursuing this course there is an obvious difficulty. When the blood is propelled onwards by the contraction of the heart, why does not the force that moves it cause it to flow backwards as well as forwards? When, for example, the right ventricle contracts, why is not the blood propelled backwards into the right auricle as well as forwards into the pulmonary artery? When the ventricle contracts, its necessary tendency must be not only to force the blood into the artery which the course of the circulation requires should receive it, but also into the auricle from which it has been just transmitted. There is no other possible means of obviating this fatal impediment to the circulation than that of placing a valve between the artery and vein. Accordingly a valve is placed there (*fig.* 55. *b*, *b*, *b*). The action of the valve is as follows:—As long as the blood proceeds in its proper course, it presses the valve close to the side of

Fig. 56.



Represents the valve placed between the right auricle and the right ventricle, the auricle and ventricle being supposed to be cut open, and the valve hanging in three great divisions; *a*, part of the inside of the auricle; *b*, part of the inside of the ventricle; *c c c*, the columnæ carneæ; *d d*, the cordæ tendineæ; *e e e*, the three great divisions of the valve.

the heart; and, consequently, prevents the valve from occasioning any impediment to the circulation. On the contrary, the moment the blood begins to flow backwards into the ventricle, it insinuates itself between the wall of the ventricle and the valve; forces up the valve from the side of the ventricle; causes it to occupy the passage between the ventricle and the auricle; and thus completely shuts up the channel. How effectually it does this is well seen in *fig.* 57, *a*, which represents the figure

Fig. 57.

Represents the figure which the three semilunar valves, placed at the mouth of the aorta, assume when distended by the refluent blood.

assumed by the three semilunar valves, placed around the mouth of the aorta, when they become distended by the refluent blood. As is clearly seen in this figure, they so completely shut up the passage that not a particle of fluid can pass backwards into the ventricle.

There is a further contrivance adopted, and one which the mind cannot contemplate without admiration, in order to render the action of the valve, placed between the auricle and ventricle, perfect. Were the membrane, which is placed in this situation, loose, it is obvious that the refluent blood would carry it back into the auricle, and thus effectually prevent its action as a valve. But it has been stated that the fleshy columns, which are placed in the wall of the ventricle, (*fig.* 56, *c*, *c*, *c*,) give off numerous tendinous threads, *d*, *d*, which are attached by one extremity to these fleshy columns, and by the other to the loose edge of the valve, *e*, *e*, *e*. These tendinous threads, like so many strings, tie down the valve to its proper situation; and being thus secured, the membrane is not only prevented from being carried by the impetus of the refluent blood too far into the auricle, but that very impetus is the means of giving it the distension and figure that are required. But the perfection and beauty of the mechanism do not stop even here. It has been stated that each of these fleshy columns may be considered as a distinct muscle: each is endowed with the peculiar property of the muscular fibre, that of contractility: each is excited to contraction by the contact of the blood just as the ventricle itself; each, therefore, by contraction shortens all the tendinous threads attached to it just at the moment that these strings require to be tightened; and they further tighten them in the precise proportion required: for the distension of the membrane by the refluent blood stretches these tendinous threads, and the stretching of the tendinous threads stretches the fleshy columns: the fleshy columns are thus still further irritated, excited, stimulated: the consequence of this increased excitation is proportionally increased contraction, and the ultimate result, increased security that the valve will be held in the precise position that is required, with exactly the degree of strength that is wanted. Thus there is accomplished here the construction of a valve, which is not only most perfect in itself, but which is endued with a property to which no other mechanism affords any parallel, a valve capable of generating a power that enables it to act with additional force whenever additional force is requisite. Among the countless instances of wise and beneficent adjustment familiar to the student of nature, there is commonly some one upon which his mind rests with peculiar satisfaction; some one to which it finds itself constantly recurring as affording *the* proof, which cannot be resisted, of the operation of an intelligence that has foreseen and planned an end, and provided for its accomplishment by the most perfect means: and surely there is nothing more worthy to become one such resting-place to the philosophical mind than the structure and action of the valves of the heart.

Valves are placed between the right auricle and ventricle; at the mouth of the pulmonary artery, between the left

auricle and ventricle, and at the mouth of the aorta.

Quantity of Circulating Blood in Man.

Each cavity of the heart may contain from two to three ounces of blood. The heart contracts four thousand times in one hour: therefore, there passes through the heart, every hour, eight thousand ounces, or seven hundred pounds of blood. The whole mass of blood in an adult man is about twenty-five or thirty pounds, so that a quantity of blood equal to the whole mass passes through the heart twenty-eight times in an hour, which is about once every two minutes. What an affair must this be in very large animals! It has been said, and with truth, that the aorta of a whale is larger in the bore than the main pipe of the waterworks at London Bridge, and that the water roaring in its passage through the pipe is inferior in impetus and velocity to the blood gushing from a whale's heart. Dr. Hunter, in his account of the dissection of a whale, states that the aorta measured a foot in diameter, and that ten or fifteen gallons of blood are thrown out of the heart at a stroke with an immense velocity, through a tube of a foot diameter.

It has been well observed, that we cannot be sufficiently grateful that all our vital motions are involuntary, and independent of our care. We should have enough to do had we to keep our hearts beating and our stomachs at work. Did these things depend, not to say upon our effort, but even upon our bidding, upon our care and attention, they would leave us leisure for nothing else. Constantly must we have been upon the watch, and constantly in fear: night and day our thoughts must have been devoted to this one object; for the cessation of the action, even for a few seconds, would be fatal: such a constitution would have been incompatible with repose.

The wisdom of the Creator, says a distinguished anatomist, is in nothing seen more gloriously than in the heart. And how well does it perform its office! An anatomist who understood its structure might say beforehand that it would play; but from the complexity of its mechanism and the delicacy of many of its parts, he must be apprehensive that it would always be liable to derangement, and that it would soon work itself out. Yet does this wonderful machine go on, night and day for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having at every stroke a great resistance to overcome, and it continues this action for this length of time without disorder, and without weariness.

That it should continue this action for this length of time without disorder is wonderful; that it should be capable of continuing it without weariness is still more astonishing. Never, for a single moment night or day, does it intermit its labour, neither through our waking nor our sleeping hours. On it goes, without intermission, at the rate of a hundred thousand strokes every twenty-four hours, yet it never feels fatigued, it never seems exhausted. Rest would have been incompatible with its functions. While it slept the whole machinery must have stopped, and the animal inevitably perish. It was necessary that it should be made capable of working for ever without the cessation of a moment, without the least degree of weariness. It is so made, and the power of the Creator in so constructing it can in nothing be exceeded but his wisdom.

Proofs of the Circulation.

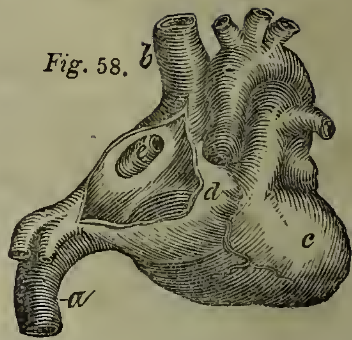
That the course of the blood is such as has now been described, is demonstrated, first, by the structure and disposition of the valves of the heart. The valves placed at the two auricular apertures are so situated as to prevent the contents of the ventricles from returning into the auricles, while the contents of the auricles are allowed a free passage into the ventricles: at the same time the valves placed at the mouths of the pulmonary artery and the aorta allow the contents of the ventricles to pass into the arteries, but prevent the contents of the arteries from returning into the ventricles. And the countless valves which crowd the venous system are all so arranged as to permit and assist the passage of the blood from the arteries through the veins, while they effectually resist its return from the veins through the arteries. Secondly, it is still more certainly proved by the effect of ligatures. When a ligature is thrown around a vein the blood accumulates in that portion of it which is most distant from the heart, while the portion which lies between the ligature and the heart continues to carry forward its contents, and soon becomes empty. When, on the contrary, an artery is subjected to a

similar experiment the reverse occurs. That portion of the artery which lies between the ligature and the heart becomes full and swollen, while the other parts become flaccid, proving clearly that the contents of these two vessels move in opposite directions, and that the natural current of the blood is from the heart to the artery, from the artery to the vein, and from the vein to the heart. Finally if the web of a frog's foot be examined through a microscope, the blood may be seen pursuing the course now described. The minute particles of which it consists are observed to flow in innumerable streams, the streams constantly intersecting each other, and occupying every point of space within the view. It is a sight which no man who has once seen can ever forget; and he who has not seen it, has not beheld one of the most curious, and wonderful, and beautiful objects which animated nature presents.

Course of the Blood in the Fœtus.

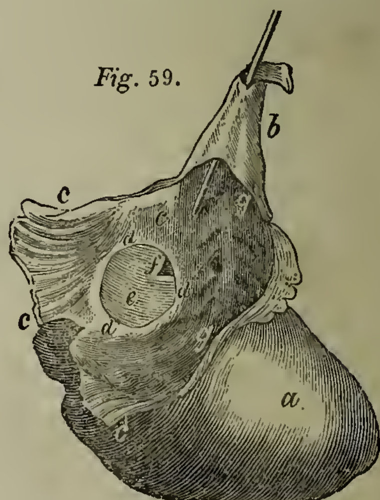
The preceding account relates entirely to the course of the circulation in the adult: it is a highly curious and interesting fact, that, in the unborn child, it is materially different. Since respiration is not only incompatible with fœtal life, but since the blood of the fœtus, or unborn child, comes to it sufficiently purified from the system of its mother, its lungs neither can, nor are required, to exert any influence upon its blood. To circulate all this fluid through these organs, while in this quiescent state, would only complicate the function, without rendering it more perfect. So much only is, therefore, sent to them as is necessary for their nourishment, and the rest is, by a beautiful but simple contrivance, passed onward to the system from the right to the left side of the heart, with the least possible loss of purity, or waste of time. To effect this, a heart, which is actually double, and ultimately intended for a double circulation, is converted for a time into a single organ; and, strange as the assertion may at first appear, man, when viewed in different periods of his existence, may be regarded as both a cold and a hot blooded animal. The right auricle is made to communicate freely with the left, by means of an oval aperture, placed in the centre of the partition which divides them (*fig*. 58); and the blood of the right ventricle is made to mingle directly with that of the left, by a communicating vessel, termed the *ductus arteriosus*, or the arterial duct, which is placed between the pulmonary artery and the aorta (*fig*. 60.) The oval hole is guarded by a valve (*fig*. 59, *e*), which, being placed within the left auricle, allows the passage of blood from the right to the left auricle only; and runs so obliquely between the pulmonary artery and aorta that, while the contents of the former vessel are encouraged into the latter, those of the latter vessel can never retrograde into the former. By means of the communicating aperture, a great portion of the blood, which enters the right, is

Fig. 58.



Represents the heart of the fœtus; *a*, the inferior vena cava; *b*, the superior vena cava; *d*, the margin of the right auricle which is here seen opened; *e*. the foramen ovale, or the oval aperture, situated in the partition which separates the right from the left auricle.

Fig. 59.



Represents the heart of the fœtus, with all the parts cut away excepting the ventricles and the partition between the auricles; *a*, the ventricles; *b*, the vena cava, with a blow-pipe in it; *c*, the wall or partition between the auricles; *g*, the musculi pectinati, or the muscular fibres of the auricle: *d*, *d*, *d*, margin of the foramen ovale; *e*, the valve of the foramen ovale; *f*, a small opening always seen at the upper part of the valve.

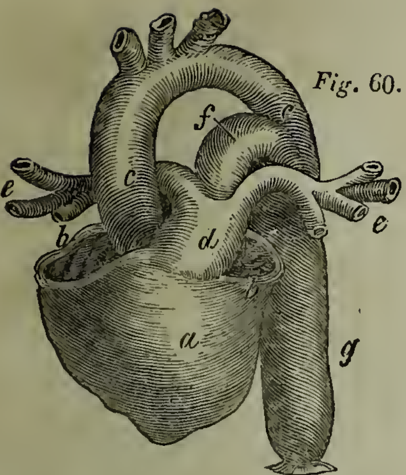


Fig. 60.

Sketch of a preparation made to show the ductus arteriosus; *a*, the ventricles; *b*, the place from which the two auricles are cut away, in order that they may be seen distinctly; *d*, the pulmonary artery, arising from the right ventricle; *e*, *e*, the right and left branches of the pulmonary artery going to the right and left lungs; *f*, the ductus arteriosus, or the arterial duct passing directly from the pulmonary artery to *c*, *c*, the aorta; *g*, the aorta increased in size by the addition of the arterial duct.

passed immediately into the left auricle, in place of being previously journeyed through the right ventricle, pulmonary artery, and lungs; and by means of the communicating vessel (the arterial duct) a great portion of the blood, which had not previously passed through the oval hole into the left auricle, but through the auricular foramen into the right ventricle, is sent directly to the arch of the aorta, to meet and mingle with the rising current as it issues from the left side of the heart. The right and left auricles are thus, as it were, thrown into one common cavity, by the intervention of the oval hole; by means of the arterial duct, the right and left ventricles unite in propelling at the same moment into the aorta the blood which they contain; and the right auricle and ventricle are made subservient to the left auricle and ventricle, instead of being supernumerary apartments in a double heart, conducting a single circulation.

The peculiarities of the fœtal circulation, it is hoped, may now be understood. The blood, which is sent from the placenta to the child, arrives at the right side of the heart, and is admitted into the right auricle. When the auricle becomes full, it contracts, part of the blood which it contains enters the right ventricle by the ordinary way, and part passes through the oval hole between the right and left auricles into the left side of the heart. That portion which passed immediately into the left side of the heart through the oval hole is sent out directly by the left ventricle into the aorta, to be distributed throughout the body; and that portion which entered the right ventricle is sent on towards the lungs, through the pulmonary artery, but, by entering the connecting branch which runs between this artery and the aorta (the arterial duct), the greater part of this second portion likewise escapes into the aorta, thus leaving only a fraction of the blood which had at first entered the right auricle to continue its ordinary journey to the lungs. After the blood has reached the aorta, it follows the usual route in its course along the body, but, in place of immediately returning to the right auricle, as in the circulation of the adult, it passes out of the body through the navel of the child by two vessels in the navel string, or umbilical cord, goes back to the placenta, and then returns by a single vein along the cord to the fœtal heart, renovated and prepared for another circulation.

As soon as the child is born, however, this modified circulation ceases. At this period two important changes occur—the connexion which had subsisted between the maternal and the fœtal systems is dissolved, and the lungs of the child begin to act. In virtue of the first change, no more blood can be received from the mother: in consequence of the second, the blood of the child must commence a double circulation. The first change will occasion less blood to be received into the right auricle, and the admission of more blood into the left will result from the second change. The relations of the fœtal circulation are thus reversed, and the very causes which formerly gave rise to its peculiarities are now employed for their removal. During the fœtal circulation, the communicating aperture between the auricles continued open, because the contents of the right auricle exceeding in quantity those of the left, the momentum of the circulation was from the right auricle to the left; and the communicating vessel which ran between the pulmonary artery and aorta likewise remained pervious, because circulation through the lungs, in their collapsed state, was difficult. But at birth, the auricular aperture closes, because the supply of the right auricle being no greater, and at first less than that of the left, the determination of the circulation

is from the left to the right auricle, and, therefore, the valve of this aperture, which lies in the left auricle, is so compressed against its walls during every contraction, that adhesion between the margins of the valve and the aperture ultimately takes place, and the arterial duct, or vessel of intercourse between the pulmonary artery and aorta, also closes, because the expanded state of the lungs encourages the passage of the blood from the right to the left cavities of the heart.

Circumstances purely physical are thus found to account for the very different states of this function in the fœtus and in the adult. The connexion of the former with its mother's system not only renders a single circulation necessary but leads to the very apparatus for its establishment; and the aërial medium by which the latter is surrounded not only requires a double circulation, but furnishes important facilities towards its execution. The auricular aperture and communicating vessel being now closed, the heart, which before was only anatomically double, is now made functionally so; and the blood, which was before limited to a single circulation, is now made to undertake a second journey. There is no parallel to the perfection of this contrivance, but the simplicity of the mechanism by which the objects required are secured; and that mechanism affords one of the most beautiful illustrations, at once of skilful adaptation and of prospective arrangement.

Powers by which the Blood circulates.

Such is the machinery by which the blood circulates and the course in which it flows. It is an interesting and somewhat difficult point to determine what is the agency by which this machinery is wrought, or what are the powers which are brought to bear upon it to put it in motion, and to keep that motion up without ceasing, without weariness, without thought, for the most part without even consciousness, during every moment of our life, through our sleeping and our waking hours.

Some have imagined that as the blood is a living fluid, it cannot be considered passive during its circulation; but that, by putting into action its own vitality, it materially contributes to its own movement. Others have studied the science of hydraulics with the hope of discovering the circulating powers, and, forgetting that man is a living being supported by vital functions, the sanguiferous system has been regarded as a clever illustration of mechanical principles working upon dead matter. It is unnecessary to say how far both doctrines are distant from the truth; and it is quite certain that many of the phenomena of this function must have appeared impenetrably obscure to the advocates of either. It was the doctrine of Harvey, that the only organ which conducted the circulation was the heart; and this opinion has been warmly advocated by many subsequent physiologists. But it has been already shewn that in many of the inferior classes of animals, a circulation may exist without a heart; its introduction being only necessary when organization became voluminous, and structure complex. In insects there is no central organ. In fishes, the branchiæ, or gills, intervene between the aorta and heart; so that the blood, after it leaves the branchiæ, must move by some agency independent of the heart; and in the human species, cases have been met with in which a circulation must have obtained for a considerable period without any central organ. A fœtus, fifteen inches high, has been described by Mr. Brodie as not having had a heart; and the mola, or imperfect child, frequently attains a very considerable size without the advantage of such an organ.

It is obvious, therefore, that however essential the heart may be to the circulation of the blood in many classes of animals, certain forms of this function may proceed without it; and it will soon be shown that even in man several other important agents are employed.

Action of the Heart on the Circulation.

When the chest of a living animal is opened and the heart exposed, the following appearances are witnessed. The right auricle is seen to contract while the right ventricle dilates; and when the right ventricle dilates, the pulmonary artery contracts. The same alternations of action take place in the left side of the heart. As the left auricle contracts, the left ventricle dilates; and as the left ventricle dilates, the aorta contracts. The two auricles, consequently, dilate together, the two ventricles contract together, the pulmonary artery and aorta are filled at the same time, and the venæ cavæ and pulmonary veins pour their contents at the same moment into the auricles. The

harmony, with which these different actions proceed, is as beautiful as the necessity of such harmony is obvious. Did the ventricles persevere in contracting after their contents had been expelled, the auricles would be unable to fill them; and did the auricles forget to contract when full, the ventricles would continue empty. As it is arranged, however, the ventricle is empty when the auricle is full, and contraction commences the moment relaxation terminates; so that as soon as the auricle is prepared to fill the ventricle, the ventricle is prepared to relieve the auricle; and the ventricle is no sooner ready to propel its contents into the artery, than the artery is also ready to receive them. This systematic alternation of giving and receiving is continued, until the blood which entered the right auricle leaves the left ventricle.

Many ingenious conjectures have been hazarded respecting the cause of this curious succession of alternate actions. The ancients believed that there dwelt an inherent pulsific virtue in the heart, which enabled it to contract and dilate alternately. Some conceived that the auricles and ventricles were antagonist muscles, and that the same cause, which operated upon the auricles as a stimulus to contraction, acted at the same time as a sedative upon the ventricles in causing relaxation. Some ascribed to an effervescence between the acid and alkalescent principles of the blood, what others traced to the *archeus*, *anima*, or intelligent agent, which was supposed to superintend the vital functions. Haller explained all upon an unknown, yet acknowledged principle, which he called irritability; and Le Gallois has endeavoured to prove that the heart depends upon the spinal marrow for all its varieties of motive power. By introducing a metallic rod into the vertebral canal, he found that the action of the heart weakened as he broke down the spinal cord, and that when it was completely destroyed, this organ had lost all power of supporting the circulation. But similar experiments have subsequently proved that the spinal marrow may thus be broken down throughout its whole extent, and yet the heart continue its action for a considerable time. It is also certain that the heart, when separated from the body, may be stimulated to contraction by being immersed in warm water, or pricked with a sharp-pointed instrument; and likewise that in an animal, which has recently expired, its action may be for a time restored, by supporting an artificial respiration. Such facts, and they might be variously multiplied, are well known, and the inference to which they tend is obvious; yet it must be admitted that there are phenomena of an opposite nature strongly indicative of the influence of the nervous system upon the heart. The blood-vessels of a palsied limb begin to diminish shortly after the attack; its supply of blood lessens as its power sinks; emaciation keeps pace with impaired sensibility, and mortification is not unfrequently the consequence of a paralyzed circulation. And as in diseases of the nervous system, the functions of the heart and arteries are more and sooner disturbed than perhaps any other; so even in health there is no organ so much under the power of the mind as the heart: fear depresses its activity, and joy excites it; it is, in short, so much the victim of mental emotion, that it is popularly called the seat of passion; and to speak in the language of the heart is considered as characteristic of sincerity, as it is of grief, to say that the heart is broken. The only legitimate inference which can be drawn from such conflicting premises is that, while the heart is not perhaps as immediately dependent upon the brain, as the brain is upon the heart, both are necessary for the efficient action of either.

The heart is a hollow muscle, possessing both elastic and contractile powers. Its contractility depends on the muscular fibres of which it is principally composed: its elasticity on the cellular tissue which, as we have seen, is mixed up with the muscular. Its elasticity is inferior to its contractility; but its elasticity is indispensable. When the heart contracts, its muscular fibres have not only to expel the blood, but to overcome the elasticity which would prevent contraction; and when it dilates, the muscular fibres relax, and allow its elasticity to operate. The one is a vital, the other a mechanical agent. Power is created by the action of contractility, but elasticity merely restores a part to its primitive condition, when the constraining force has ceased to operate.

The cause of the heart's contraction is the entrance of blood into its cavities; the cause of the heart's dilatation is the action of its elasticity when its contractility has ceased. In this manner may

be explained what have been called the *systole* or contraction, and the *diastole* or dilatation of this organ. The elastic power facilitates the reception of blood into the heart; the contractile power effects its departure from it. The elastic power opens the auricle, the contractile power closes the ventricle. When the contents of the auricle have been expelled, as soon as the contractile power has so relaxed as to give the elastic power the superiority, dilatation commences, and proceeds until the walls of the auricle have resumed their natural state. A vacuum is, therefore, formed within the auricle, and the blood, which is urged forward to the heart along the veins, is invited by this vacuum into the auricle. Elasticity and contractility are, then, the two great powers by which the heart acts.

Supposing that the quantity of blood taken into the heart during each dilatation be two ounces and a half, that the heart contract seventy-five times in a minute, and that thirty pounds represent the quantity of blood circulating in the body of a moderately sized man, the whole mass of blood will pass through the heart twenty-three times every hour, and an entire circulation will be performed every three minutes. The time spent during one circulation may thus be easily ascertained; but it is more difficult to discover how far the action of the heart extends along the arteries, and at what rate the blood travels in different stages of its journey.

From experiments carefully made and frequently repeated, it is believed that the left ventricle projects its blood into the aorta with a velocity equal to twenty-one feet in the minute. By inserting a glass tube into a large artery, Hales found that the blood rose eight feet and three inches above the level of the left ventricle during every contraction of the heart, and hence infers, that the blood would rise seven feet and a half high in a similar tube fixed into the carotid artery of a man. "The internal area of the left ventricle of the heart (he observes) is equal to fifteen square inches; these multiplied into seven feet and a half give 1350 cubic inches of blood, which press upon that ventricle when first it begins to contract; a weight equal to 51—5 pounds."

It is certain, however, that if the velocity with which the blood leaves the left ventricle, supposing it to be equal to twenty-one feet in a minute were maintained throughout its whole course, three minutes could not be spent in a single circulation. Several of the reasons why this cannot be the case will soon appear, and it is not unlikely that the power of the heart has been over estimated. Borelli conceived that it was equal to 180,000 pounds; Senac reduced it to 4.00; and Keil diminishes it to the insignificant fraction of eight ounces. The amazing discrepancy, which such calculations betray, is a tolerable proof that little importance is to be attached to any of them; and it was to be expected that they, who looked to the action of the heart alone for the agency by which the blood circulates, would be tempted, for the sake of system, to ascribe to it an undue influence.

Action of the Arteries on the Circulation

By such physiologists the arteries were contemplated as lifeless and passive tubes, useful only because connected with a living and acting organ. But it has been already stated, that a circulation may be conducted even in the human system without a heart; that in insects there is no such organ, and that in fishes two-thirds of the blood with which they are supplied are circulated by means of vessels only. Since, however, this function may exist without a heart, while an artery is always necessary, it is obviously absurd to attempt to explain the circulation upon mere hydraulic principles, or to ascribe to the heart the entire credit of its performance. In living beings the agency of machinery must ever be studied in connexion with the influence of life. Each is equally necessary to the establishment of function. No physical process can be conducted by life without machinery, and machinery without life cannot execute any physiological function. Were arteries lifeless tubes, attached to the heart for the sake of convenience, as leather pipes in a water-engine are connected with the piston, the science of hydraulics might be legitimately applied to the action of these vessels, and to estimate the force of the heart's agency would be to measure the strength of the circulating powers.

This plan has been attempted, but it has failed, and the heart has been invested with a degree of force quite incompatible with the structure of such an organ, in order to account for phe-

nomena which were not to be explained upon so limited a system. If the capillary extremity of an artery be placed in a microscope, it will be seen to contract and dilate as regularly as the heart. If the aorta be tied as it issues from the heart, the blood which it contains beyond the ligature will be urged forward as usual into the veins. And if the heart be wholly removed from the body, the circulation may be observed to go on for some time afterward in the capillary vessels. Many experiments of this kind were performed by Spallanzani. The heart of a salamander was opened, and the blood continued to flow through the vessels for twelve minutes after the operation. The heart of a tadpole was cut out, yet "the circulation was maintained some time in several ramifications of the tail; while the motion of the blood in the large veins became augmented, that in the accompanying artery took a retrograde course towards the heart." The heart of the chick in ovo was destroyed immediately after contraction; "the arterial fluid took a retrograde direction, and the momentum of the venous blood was redoubled. The circulation continued in this manner during eighteen minutes."

Like the heart, therefore, the arteries are endowed with the properties of contractility and elasticity; and a little consideration will be sufficient to convince us, that were they not both elastic and contractile tubes, they would be unqualified for discharging the offices assigned them. The moment the left ventricle has poured its blood into the aorta, several retarding causes begin to operate, through which the velocity first imparted to the departing current gradually lessens as it moves to a distance from the heart. The friction between the blood and the sides of the vessels through which it moves,—the many curves and angles which it encounters while passing along tubes laid in every organ of the body—and the increasing area of these tubes as they ramify, are obstructions of such influence as would render it impossible for the heart to conduct the circulation without assistance. Since the area of the aorta or arterial trunk is less than the conjoined area of all its branches, it follows that the arterial system constitutes an inverted cone, the apex of which is in the heart and the base in the capillaries. And since it is a well-known hydraulic law, that the velocity of a fluid in a tube is in an inverse ratio to the area of that tube, it likewise follows that the velocity of the blood along the arterial system must, in obedience to this law, decrease as it proceeds from the centre to the circumference.

Now, nature has done every thing to weaken the influence of these retarding causes. To lessen the effects of friction, the arteries are made elastic; to counteract the influence of curves and angles contractility is afforded; and to neutralize the tendency of a law which diminishes the velocity of a fluid as the vessel through which it moves increases, this contractile power augments as the vessel decreases. In consequence of the first provision, the impulse of the heart is transmitted along the vessel to as great a distance and with as little loss of momentum as possible; by the second a new impulse is added to the first; and by the third the strength of this impulse rises as that of the first declines. Were the arteries unyielding vessels, friction would operate at every impulse of the heart without the control of an opposing principle; but, by making them both elastic and contractile, and proportioning these properties to the varying necessities of the case, the impelling powers and resisting forces are equalized. Some from having overlooked this provident arrangement, have maintained that the velocity of the blood in the aorta is 1100 degrees quicker than that with which it circulates through the extreme vessels; and Hales has concluded that the blood in the capillaries of a frog's foot, which he says travels at the rate of two feet every minute, is six hundred and fifty times slower than that in the human aorta, the average velocity of which he estimates at eight inches in a second.

But many ingenious and well-conducted experiments have been made by Haller and Spallanzani, which clearly shew that, when the body is in a state of health, there is a very trifling difference between the velocity of the blood's movement in the large trunks and the minute vessels. When a small artery was opened, the blood issued with as much force and to as great a distance as when drawn from a large one; and when the microscope was employed, the blood in the capillaries frequently seemed to move even more rapidly than that in the trunks.

If it be considered how the two circulating powers already described—elasticity and contractility—are proportioned throughout the arterial system, it will not appear strange that the fact should be as is now stated. It is probable that the aorta is muscular as it issues from the heart, and that the farthest point of its most minute branch is elastic: but these two powers will not be found in the same degree in these two forms of the same vessel. Elasticity diminishes as we proceed from the heart; muscularity diminishes as we approach it. Their conditions are inverted. The stronger the contractility the weaker the elasticity; and the weaker the elasticity, the stronger the contractility. So that, as the strength of the heart's impulse upon the blood diminishes as the current leaves the centre, the strength of the contractile power in the smaller arteries through which it has to pass increases. And as the elasticity of the large arteries, which to them is essential, would be injurious to the small ones, this principle gradually decreases with the decreasing artery, until the capillary vessel becomes almost exclusively a muscular tube. A large artery near the heart needs not much contractile power, because the action of the heart gives a degree of momentum to the blood passing through such a vessel, which would not only render strong action in the vessel unnecessary, but inconvenient. But as this momentum weakens through the effect of the retarding causes already mentioned, increasing power in the artery is indispensable as a compensation for the decreasing influence of the heart. And since elasticity and contractility are antagonist principles, it were in vain to increase the contractility of the small artery while it was permitted to retain the elasticity of the large one, because any increase of its contractile power would be rendered useless by the preponderance of its elastic force. The elasticity of a large artery preponderates, because this elasticity enables it to dilate when the heart contracts, and thus to increase the action of the heart by diminishing the friction of the vessel; and the contractility of a small artery preponderates because this contractility enables it to make up for the deficiency of the heart's action, and thus to preserve the circulation in a tolerably uniform state.

Circulation through a large artery is, consequently, more an hydraulic, through a small artery, more a vital process. Hence, in the sturgeon the aorta is bony, and the root of the same vessel is often ossified in man, without producing any change in the character of the circulation. The heart is the central organ by which the blood is put in motion, and circulates toward the circumference; the capillaries are the peripheral organ, by which the motion at first given to the blood is supported and assisted in returning toward the centre.

Action of the Veins on the Circulation.

It has been observed, that in the structure, course, and arrangement of the veins, there are several points which distinguish them from arteries. In the first place, they are thinner and less elastic, and muscularity has been generally denied to them. Secondly, they are crowded with semilunar folds of their lining membrane, termed *valves*, which are so disposed in their interior, as to offer no resistance to the blood in its progress to the heart, while they render any other course impracticable. Thirdly they are generally not so deeply-seated as arteries, but are comparatively superficial, many of them being covered only by the external skin. Fourthly, they are much more numerous than arteries, and anastomose much more frequently with each other; and, lastly, they are more capacious, and are supposed to contain two-thirds of the entire mass of blood. Now, a knowledge of these peculiarities will teach us the action of these returning vessels.

In several of his experiments upon salamanders, Spallanzani ascertained that the motion of the blood, during its return through the veins, was materially accelerated at every contraction of the heart. And it has been shewn, that the capillary arteries, in consequence of their increased contractility, operate at the circumference as the heart does at the centre of the circulation; differing in nothing but their degree of action. By the heart, or central power, the blood is propelled into and urged through the arterial trunks. As these trunks lessen into branches, the propelling power of the heart diminishes, while the contracting power of the tubes increases; and when the blood has reached the capillary or extreme vessels, it is then fully under the influence of a strong muscular agency. This muscular agency of the capillaries, aided by the impetus of the blood impelled onward from behind by

the heart and arterial trunks, enables this fluid to return through the veins. It must be recollected, however, that although we are thus tracing the different stages of the blood's progress through the system, it never stops in any period of its course; that the action of the heart is constant, and that the arterial trunks are ever full.

When a quantity of blood, then, has reached the capillary arteries, and is ready to be transferred into the capillary veins, three powers at least are in operation to effect its passage. The first is the muscular action of the arterial capillaries, the second is the action of the heart and arterial trunks, and the third is the momentum of a large column of blood already in rapid motion. These three agents, probably assisted to a small extent by capillary power, convey the blood, as it comes from the extremities of the arterial trunks through the capillary system, into the beginnings of the veins; but how far they are capable of propelling it along these vessels, it is not so easy to ascertain. For our present purpose it is enough to know that their action must extend a considerable way, and that in the structure, course, and number of the vessels through which the returning fluid has to pass, every facility is afforded to it. The veins are large and freely anastomose, in order that if any obstacle occur in the circulation of one tube, the blood may make its passage through another. They are crowded with valves, in order that the blood, which they contain, may be prevented from pursuing any other than its proper course, in order that the weight of the returning column may, as far as possible, be taken off the propelling powers, and in order that external pressure, or muscular action, or any neighbouring influence may be rendered available to the common object—the ascent of the blood in the veins. They are much less tortuous than arteries, that the impediment from curves, angles, and lateral friction may be small; and while the arterial system forms an inverted cone, the veins constitute a cone set upright, so that the returning blood has the advantage of a law which was a serious impediment to its progress along the arteries. When inverted and upright cones are here mentioned, we speak with relation to the course of the blood through them, and not to the position of the cones themselves. As to abstract position, the arteries are as much an upright cone as the veins; since the apices of both cones terminate in the heart. But while the arterial blood moves from the apex to the base, the venous blood moves from the base to the apex; so that the current of the blood in the arteries, being viewed in relation to the position of the cone, is said to be along an inverted cone, but along an upright cone when in the veins.

Every facility being thus afforded to the return of the venous blood to the heart, the powers already specified operate with the greatest advantage; and when their influence begins to weaken as the current approximates the centre, a new agency comes into play, which must now be mentioned.

Suction power of the Lungs and Heart.

While treating of the action of the heart in propelling the arterial blood into the aorta, we said that the ventricle dilated as the auricle contracted, that the auricle dilated as the ventricle contracted, that the cause of the heart's contraction was its muscularity, that elasticity was the cause of its dilatation, and that this elasticity arose from the presence of a large quantity of cellular tissue, which is mixed up with the muscular fibres of this organ. It was likewise hinted, that one cause which assisted the auricle in filling the ventricle, was a partial vacuum formed within the latter by the action of its elasticity, and it will now appear that the same cause assists the venæ cavæ or trunks of the venous system, in filling the auricle when the ventricle is full.

If a caoutchouc bottle be filled with water and compressed with the hand, the fluid will be expelled from its mouth with a velocity proportionate to the compressing force. But the moment the pressure is removed, elasticity begins to operate, and if the mouth of the bottle be now immersed in water, a considerable quantity of this fluid will be drawn up into the bottle, in consequence of the vacuum formed within it. Let this illustration be applied to the action of the heart, and the nature of the new agent, which aids the other powers in returning the venous blood to the right auricle, will be easily understood.

When the right ventricle has poured its contents into the pulmonary artery, the auricle contracts, and immediately fills it. But the auricle has no sooner contracted than its elasticity again causes it to dilate, and thus a vacuum is formed

at the very extremity of the venous system. Meantime the blood, which in returning through the veins, being pressed upon in every direction from behind, moves on toward the heart, comes at length within the influence of this vacuum; instantly the suction power generated in the auricle begins to operate, and completes the circulation by drawing the rising current into the cavity of the auricle.

To revert again for a moment to our illustration of the elastic bottle. Suppose that, in place of allowing this bottle to be exposed to the action of the external atmosphere during the experiment, it be introduced within the exhausted receiver of an air-pump, while, at the same time, by adjusting a pipe to its mouth, we connect the bottle within the pump with a vessel of water on the outside; it is evident that, since the pressure of the air is removed from the surface of the bottle, while it continues to act upon the surface of the water, the fluid will be drawn through the pipe into the cavity of the bottle with a very considerable force; with a force regulated by the proportion which the surface of the water bears to the surface of the vacuum within the bottle.

Now, it is supposed that the heart, during a healthy state, is placed in circumstances very similar to those in which the elastic bottle stands while under the receiver of the air-pump. Until, however, we proceed to the subject of respiration, and have the anatomy of the pulmonary system before us, it will be impossible to present the reader with any intelligible description of this doctrine. For the present, he must rest satisfied with the assumptions that such a vacuum exists; that during inspiration, the cavity of the chest being much enlarged, the pressure of the external atmosphere upon it is materially diminished; that the parts which it encloses are for the time in a partial vacuum; and that, from the connexion subsisting between the heart and lungs, a considerable portion of this vacuum takes place in the cavity of the pericardium, or bag, which surrounds the heart. The consequence is, that the heart works within the pericardium as the elastic bottle works within the exhausted receiver; with this difference, that the vacuum within the latter is constant, while it only occurs in the former during every inspiration.

If a ligature be put around a vein, the blood contained by that portion which lies between the ligature and the heart, continues, without interruption, to pursue its course to the auricle; proving that, although all communication has been thus destroyed between this section of blood and the general current, there is still some power existing between the ligature and the heart. The following experiment is given to show that the influence which this suction power exerts upon the course of the venous blood is not only certain, but considerable. The left jugular vein of a horse was exposed and tied. About an inch below the ligature a large-sized flexible catheter, having a spiral glass tube adjusted to one end, was introduced into the vein by the other extremity, pushed down toward the heart as far as it would freely go, and preserved in this situation by having a ligature thrown around it and the vein. The point of the spiral tube, which had an aperture in it that had been hitherto closed by the finger, was now immersed into a cup of water, coloured with Prussian blue, and the finger was removed. The moment the tube was introduced into the cup the blue fluid rose rapidly in the tube. "The sun," says Dr. Barry, "happening at the moment to shine strongly on the tube, I saw in the most satisfactory manner the undissolved particles of blue pass up from the cup and round the spiral during inspiration, and halt and return slowly towards the cup during expiration. Not a drop of blood was seen to enter the tube, but bubbles of air sometimes appeared upon the surface of the liquid in the cup during expiration. The breathing being audible allowed me to keep my eye steadily fixed upon the motion of the liquid, and to ascertain, beyond all possibility of deception, that this motion was entirely dependant upon the movements of respiration."

The strength of this suction power in the heart is not easily measured, nor is it known with certainty how far along the venous system its influence extends; but it is obvious, from the very structure of the heart, that such a power does exist within it; and, from the observations now made, it appears that this innate suction power of the heart is materially increased by the elasticity of the lungs; or, in other words, that the heart is an elastic muscle placed within a vacuum. Viewing it, therefore, as both a forcing and a suction pump; as a hollow organ which empties its cavities by

contraction, and fills them by elasticity, many phenomena receive elucidation which it would be otherwise difficult to explain. The superficial course of the veins, the deep-seated position of the arteries, the continuous stream in which venous blood flows, and the interrupted current of arterial blood; the strong elastic structure of arteries, and the pliant compressible texture of veins; the turgidity of the veins of the neck and face during expiration and coughing; the great size of the right auricle over the left; the theory of palpitation, and the cause of the pulse;—these and many other interesting points, which our limits prevent us from noticing more largely, can be accounted for when it is known that atmospheric pressure is to be enrolled among the circulating powers, as second only in importance to contractility. The veins are pliant and superficial to give full effect to the action of the atmosphere; while the arteries are deep seated to avoid pressure, and elastic that they may, after yielding to the impulse given to the passing current by each pulsation of the heart, assist this organ by their reaction in moving the vital fluid toward the capillaries. The current in the arteries is salient or interrupted, because it depends upon the alternate contractions of the heart and dilatation of the arteries; while that in the veins is continuous, because it is moved on by more continuous agents. For the same reason is it that there is an arterial, but no venous pulse. This phenomenon is strongest at the heart, because there contraction is the strongest; and it gradually declines as we leave the centre, because as the blood departs from the centre, it is leaving the principal impelling agent; and, therefore, the impression made upon the artery at each pulsation of the heart lessens as the distance between it and the heart increases.

General Remarks upon the circulating Powers.

Such, then, are the principal agents by which the circulation in man is conducted. Some others have been mentioned, as contraction of the muscles, pressure of the viscera, the movements of the diaphragm, (of which we shall speak immediately,) and capillary attraction. But, although all of these may be considered auxiliary agents, their action must be always trifling, and may be sometimes adverse. Contractility of the heart and capillaries, elasticity of the heart and arteries, and suction power of the heart and lungs, are the three chief circulating agents, to which the execution of this important function is to be ascribed; and the consummate wisdom, with which these agents are so adapted to the varying circumstances of the circulation, can be only imperfectly estimated even when fully understood.

We have seen that the force of the heart's action has been fixed at a certain number of pounds and grains, just as we might take the weight of a piece of dead machinery, and that the velocity of the blood has been measured throughout the different stages of its course, with an inch and line calculation. But the folly of such estimates must now be obvious. As the relations between the moving agents are ever changing, the degree of motion which they generate must be equally variable. The influence of the heart upon the vital current varies with the distance; the contractility of the arterial trunks increases as they leave the heart; the elasticity of the arterial capillaries diminishes as they approach the veins; and, although the absolute pressure of the atmosphere upon every part of the external surface of the body must be the same, that is, fifteen pounds upon every square inch, the operation of a vacuum within the chest will render the effect of this pressure upon the motion of the venous blood greater in a direct ratio to its proximity to the vacuum. Thus, in perhaps every inch of sanguiferous vessel there is a new combination of the sanguiferous agents; and it is, therefore, idle to circumscribe within one general calculation the operation of powers, whose proportions are as different in different parts of the system, as the nature of the tissues through which the blood circulates.

Besides, in different individuals, and even in the same individual at different periods, the force of the heart's action and the activity of the vessels are very various. In the melancholic the circulation is languid; but in the sanguine it is quick. When enlivened by hope, or encouraged by prosperity, the vital current flows with ease and freedom; but when grief or adversity sinks the spirits this function is sure to sympathize. In youth the pulse is frequent; in manhood it is firm; in age it is weak and slow. In short, the heart is so en-

tirely the slave of mental emotion and physical circumstance, that its action may alter every hour in the day, or every minute in the hour; and the only certain facts which we can vouch for on the subject of the blood's velocity are, that it is somewhat greater in the large arteries than in the small, and somewhat less in the small veins than in the large; that as it issues from the left ventricle and enters the right auricle it is quicker, and as it passes from the arteries into the veins slower, than during any other periods of its course.

Uses of the Circulation.

The objects for which this complicated function has been so perfectly established, and is so faithfully maintained, are many and important. Nutrition, secretion, respiration, absorption, sensation, and motion, depend upon its performance. No new part could be formed, no new fluid could be elaborated, no excrementitious matter could be removed, no sensation could exist, and no motion could be effected without a heart, arteries, and veins. The process of digestion on the one hand would go on in vain, and the function of absorption, on the other, would be useless. Were there no arteries to convey the chyle, which has been elaborated in the stomach, to every organ, digestion might proceed for ever without supporting life; and were there no veins to receive the refuse matter of the system from the absorbents as they take it up, nutrition could not possibly be accomplished; the wheels of life would be clogged with excrementitious matter, the removal of which is as necessary to existence as the deposition of nutrient particles. To enter at present, however, into subjects of such extent would be irrelevant. Some of them will soon come before us in a specific form, and others will be noticed with more advantage in another place. A few general observations will be sufficient to establish their importance, and also to shew the intimate connexion which the circulation has with every other animal function.

The anxiety which nature exhibits to supply every organ and tissue with sufficient nutriment, is apparent in the minute distribution of the blood vessels. There is no part so small as to be overlooked, and no member so large as not to be abundantly supplied. There is no texture so impenetrable, which is not traversed by giving and receiving vessels; and there is no organ so distant which arteries do not reach, and from which veins do not rise. From microscopical observation, Leuwenhoeck was induced to conclude, that there were upwards of 1,000 different circulations within every square inch of the human body; and such minute distribution of the blood is not a more striking feature of this function, than the undeviating accuracy with which every nutrient particle of the general mass is deposited in its proper place. Osseous matter is laid down where bone is necessary; fleshy fibre is formed where muscle is required; and cellular tissue is secreted where neither bone nor muscle could be substituted. Perhaps, in the wide range of Nature's splendid operations, there is not to be found a more perfect, or a more extensive series of effects, resulting from a less complicated piece of mechanism, than is witnessed in the circulating system: a mechanism whereby tissues the most different are constructed out of the same fluid, and vessels externally alike elaborate secretions which have scarcely one point in common. Between the blood going to the stomach, and that which supplies the kidneys, no difference is discoverable; yet the fluids secreted by these organs are totally dissimilar; the vessels which supply the teeth and those which support the brain, appear externally alike, yet there are not two substances in nature more opposite than nerve and enamel. Muscular fibre is never deposited where cartilage was wanted; bile is never eleminated where saliva should be formed. Each tissue is deposited in its proper place; and not only in its proper place, but in its proper time; and not only in its proper time, but also in its proper quantity. When a bone is broken, osseous matter is immediately thrown into the fracture by the vessels of the part. When a nerve is divided, nervous matter is brought to the divided organ, and the nerve is healed. When cuticle has been destroyed, a new layer of skin is instantly substituted. And when a piece of flesh has been cut out, granulations instantly arise, and fill up the cavity which had been formed. But no sooner has the bone united, than the influx of ossific particles ceases; and the moment that granulation has raised the wounded part to a level with the surface, the deposition of muscular fibre stops, and

the formation of skin begins. Did the production of skin commence before granulation had filled up the cavity, deformity would be the consequence; or did granulation continue after the cavity had been filled up, the formation of skin would be prevented. Granulation continues, therefore, as long as it is required, and ceases when its continuance would be hurtful, and the secretion of skin begins only when the other process has been completed, and terminates as soon as the part is perfect.

Among the many objects contemplated in the circulation of the blood, one of the most important is its purification in the lungs. It has been already shewn that in birds and the mammalia, a second heart is added to the ordinary circulating system of cold-blooded animals, for the specific purpose of enabling the blood to undertake a second circulation through the lungs, previously to its distribution throughout the body. This lesser circulation in man is as constant and as necessary as the first; and the objects which it accomplishes are of the very same nature with those attained by the general circulation. During the passage of the blood through the body, nutritious matter is thrown out, and refuse matter is taken in; solids are formed, and fluids are eleminated: and during its passage through the lungs, vital properties which it had lost are received, and noxious qualities which it had contracted are removed. Secretion and nutrition are thus performed by both circulations; but before the nature and extent of the changes which the blood experiences by respiration can be duly estimated, the anatomy and theory of this function must be understood.

On Respiration.

It has been already observed, that wherever there is an organ appropriated to the function of digestion, there must be some kind of circulating system for conveying the digested nutriment where it is required. In like manner, wherever there are organs appropriated to the purposes of the circulation, there must be a respiratory apparatus for renovating the blood, as it deteriorates in its passage through the body. These three functions are inseparably connected. Stop the circulation, and digestion will cease; destroy digestion, and the circulation will cease; and let respiration be arrested, and both of the other processes will soon be at a stand. Chyle is not more necessary for the formation of blood, than air is for its purification; and venous or deteriorated blood is as useless to the general system as chyle, before it has been subjected to the influence of the air. The lungs may thus be regarded as a second stomach, and respiration as a second digestive function. When food enters the stomach, its nutrient particles are separated from the crude mass and converted into chyle. When air enters the lungs, its vital properties are separated for the purification of the blood. The nutritious ingredients of both substances are extracted and made subservient to the purposes of life, and their residual principles are expelled as useless and hurtful. The stomach digests food, the lungs digest air. Digestion is necessary to form chyle, and respiration is necessary to convert that chyle into vital fluid; so that the proper animalization of our food is completed in the lungs, and not in the stomach.

"To breathe and to eat" are expressions, therefore, more synonymous than at first view they may appear; and "to expire and to die" have been long known as different modes of communicating the same idea.

The intimate connection between digestion and respiration is still more strongly shown by the fact that in many animals, of which the simple structure is incompatible with complex function, the same organ is made to serve both as a digestive and a respiratory apparatus. In the lowest forms of zoophytes, the skin both respires and digests,—inhales both air and water. In many insects, a portion of the intestinal canal performs the office of lungs; and in some the intestine opens into the respiratory cavity. Even in man it is certain that the skin is a breathing and an absorbing organ; and calculations have been made by physiologists relative to the quantity of air it expires and of water it inhales, throughout the day. Finding, then, that the same texture which forms blood can also purify it; and having seen, when on the subject of the circulation, that the dorsal vessels of insects might be considered, with as much propriety, an intestinal canal as the first rudiment of a circulating system, it is natural to expect that there should be as great a variety in the structure of the respiratory apparatus as in the ma-

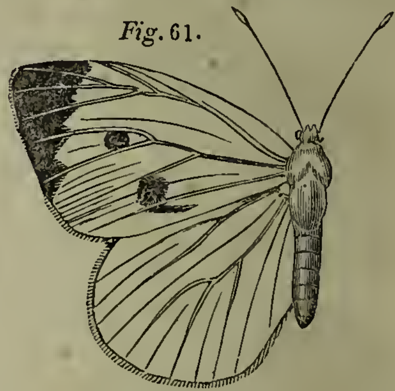
chinery of the digestive and circulating functions, and that the steps by which it rises to its most perfect state should be analogous.

The habits of different animals are so varied, and the elements which they inhabit so opposite, that to support a function so universal as that of respiration, and for the efficient discharge of which a constant supply of air is necessary, requires a mechanism difficult of contrivance. Animals which live in water cannot breathe by the same organs as those which live in air; and worms, which lie buried in the bowels of the earth, must exercise a very different function from birds, which respire in elevated regions of the atmosphere. Nature has accordingly adapted her form of apparatus to the necessities of the animal, and the success with which this adaptation has been made will be abundantly apparent as we proceed.

In some creatures, whose simple systems require little nourishment and admit of little expenditure, this function is exceedingly limited, and no specific organ is set apart for its performance. In the *hydatid*, for example, which is merely an animal bag filled with fluid, respiration is conducted as it is in the vegetable, by the surface of the skin; and in zoophytes generally the blood is aërated by the same organ which absorbs the nutriment out of which it is made. In such beings the best glasses have as yet failed to discover a distinct respiratory apparatus; and, therefore, some have concluded that they do not respire. But when the air with which they have been for some time surrounded, is examined, it exhibits those alterations in its properties which respiration is known to make; and when they are immersed in fluids, from which all air has been expelled by boiling, they languish and die. Although, therefore, there be every reason to believe that the skin, even in the most perfect systems, has some community of office with the lungs, respiration by the skin must be regarded as the first and lowest form of this function. And when it is considered that the majority of such creatures as respire in this way are inhabitants of water, it will be evident, as well from the inconvenience of the medium as from the imperfection of the apparatus, that in them little air is necessary for the purposes of life.

When we ascend another step however in the scale of being, this function is more amply developed. The air is no longer confined in its action to the surface; it has access to every part of the body by means of air-tubes, called *tracheæ*, which are not unlike arteries in form and distribution (*fig.* 61.) They circulate air as the arteries do blood; they send branches into every part;

Fig. 61.



Represents the distribution of the tracheæ in the wing of the butterfly.

and they open upon the external surface by apertures, called *stigmata*, (*fig.* 62, and *fig.* 63,) which are differently

Fig. 62.

Lateral stigmata, as seen in the bee-worm

Fig. 63.

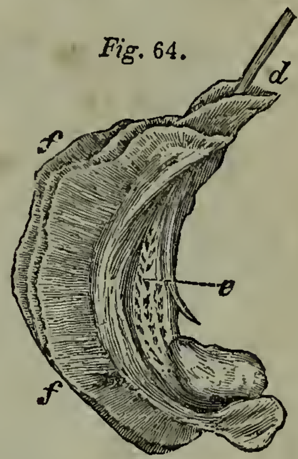
The Microscopic Louse, shewing its surface covered with spiracula.

formed, and exhibit great variety in their number. In *grasshoppers* they consist of fissures formed of an anterior

and posterior lip, which being surrounded by muscular fibres, can close or open at pleasure. In the *willow caterpillar* they are circular, and in the larva of the *cockchafer* they are guarded by a cribriform membrane, through small apertures in which the air is admitted. Since there is no texture or organ from which these air-vessels are excluded, not even the membranes composing their own trunks, the bodies of such insects as breathe by tracheæ may be looked upon with some force of analogy as little else than lungs. To have set apart in them a single organ, large enough for the purposes of respiration, and yet proportioned to the size of the general system, would have been impossible. From the habitudes of insects, it was much better, and from the peculiarities of their circulation, it was much easier, to send air to their blood, than it was to send their blood to the air. In them, accordingly, the respiratory and sanguiferous systems are reversed, when they are compared with those which obtain in man. In the human system it is the blood which goes to be purified by the air; but in insects it is the air which goes to purify the blood. In insects the body is traversed with air-tubes in place of blood vessels, and their whole system breathes; but in man the respiratory apparatus is limited to a certain spot, and the function is performed by a single organ. The quantity of air consumed by such animals is large in proportion to their size; and when the active habits which distinguish many of them are considered, the relation between the extent of this function and the energy of life can scarcely be overlooked. Insects among the cold-blooded animals are what birds are among the hot—the only class which can fly, and most of those among them which have no wings, as the common *centipede*, excel in a vivacity of habit and tenacity of life. Several species of this class, which are obliged to breathe under water, and yet are furnished with tracheæ, manage it by a very simple contrivance. In consequence of the glutinous matter with which the hair upon their skin is covered, the water is prevented from coming into contact with their surface; so that they literally breathe within an air-bubble, and swim in a kind of natural diving-bell. The *water-spider* and *water-beetle* belong to this description of insects. The *nepa* is also an aquatic insect, but not being encompassed with an air-bubble, it is compensated for the want of it by having respiratory tubes near the anus in the form of long bristles, through which it can obtain air from the surface of the water.

The ordinary method in which aquatic animals, that have to remain constantly beneath the surface of water, respire, is by *branchiæ*, or *gills* (*fig.* 64.)

Fig. 64.



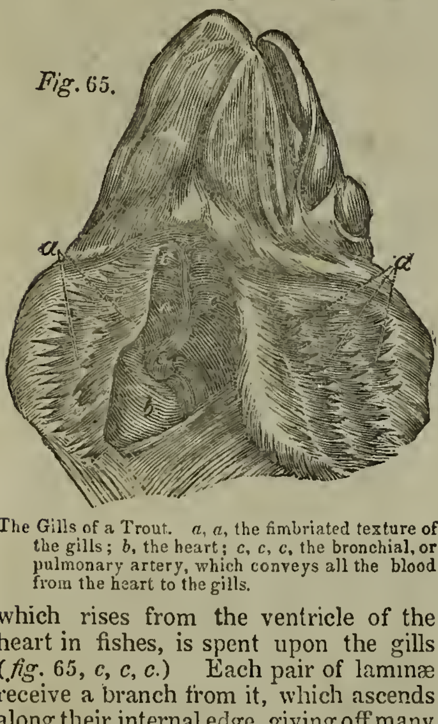
Gills of an Oyster. *d*, the triangular canal through which water is sent to the gills; *e*, the holes by which water is sent to every feather of the gills; *f*, *f*, the fimbriated extremities of the gills.

Many insects and worms, all the crustacea and fishes, breathe by gills only. These organs are very different in construction, situation, and number. In the *thetis* they appear as fourteen distinct tufts on each side of the back. In the *glaucus* they are fin-shaped. In some they are disposed in the form of tiles, in others they are pencils of small filaments. Sometimes they are situated upon the external surface, but more generally they are found in the interior of the body. In the *decapoda* they are attached to the base of the feet. In the *branchiopoda* they are placed under the tail and fins, and in the *cephalopoda* they are enclosed within a bag, which communicates externally by a funnel-shaped aperture upon the neck. This bag is muscular, and can be filled and emptied as fresh water is required for the branchiæ. In the *aphrodite aculeata* their number amounts to forty pairs; the *lumbricus marinus* has fourteen pairs, which occupy the middle of the back; and in the *sepiæ* there are two only, one on each side of the peritoneal sac.

The branchiæ in *fishes* are situated on each side of the neck, and have a free

communication with the mouth, of which they may be considered as forming the back part. They are composed of laminæ, fixed by their base to the convex sides of cartilaginous arches, but free and unattached at their superior extremity. These laminæ are long, narrow, and pointed, and set so closely to each other that they resemble the barbs of a feather, or the teeth of a comb (*fig.* 65, *a*, *a*.) The pulmonary artery,

Fig. 65.



The Gills of a Trout. *a*, *a*, the fimbriated texture of the gills; *b*, the heart; *c*, *c*, *c*, the bronchial, or pulmonary artery, which conveys all the blood from the heart to the gills.

which rises from the ventricle of the heart in fishes, is spent upon the gills (*fig.* 65, *c*, *c*, *c*.) Each pair of laminæ receive a branch from it, which ascends along their internal edge, giving off many lateral branches as it proceeds. When it reaches the apex it pours its blood into returning vessels, which unite after they leave the gills and form the aorta, by which the rest of the body is supplied. During this circulation of the blood upon the gills, the required alterations are effected, and the use of these laminæ is to afford a sufficient surface for the play of vessels, that the air contained within the water which the fishes swallow, (in order to drive it among the branchiæ,) may act upon the largest quantity of blood with the greatest possible advantage. The extent of surface thus obtained is very great. Monroe has calculated that in the gills of the *skate* it is nearly equal to the whole external surface of the human body, or to more than fifteen square feet. Along this vascular surface the water is made to play with considerable force, that the air suspended in it, by being more strongly impinged against the coats of the blood-vessels, may more certainly act upon the blood which they contain.

Three different types of the respiratory function have now been noticed. In zoophytes and a few species of worms, the external skin is the only breathing organ. A very large proportion of insects respire by tracheæ, or air-vessels, and aquatic animals breathe by means of branchiæ, or gills. The next decided step, which is taken towards the establishment of a more perfect function, is the introduction of bodies called *lungs*, which are membranous bags, divided into cells, and adapted for containing air and blood.

But between this and the preceding forms a few animals are found, whose respiratory apparatus may be mentioned as the connecting link. These are possessed of a double set of breathing organs—branchiæ and lungs. By the former they are connected with fishes, insects, and worms, and by the latter, with mammalia, birds, and reptiles. In the *siren* there are three tufts, or branchiæ, on each side of as many vertical slips placed in succession behind the head, and through which water received by the mouth is forcibly discharged. In the *proteus* there are likewise three branchiæ of a deep-red colour, which open by three distinct apertures upon the sides of the skull. But in both siren and proteus there are, besides these aquatic organs, two cylindrical bags situated in the abdomen, which act the part of lungs. Each of these bags consists of a single cavity, internally lined with a very vascular membrane, and communicating with the external air by an air-pipe or trachea, which opens upon the surface between two rounded margins. The *tadpoles* of frogs, toads, and salamanders exhibit a similar union of respiratory organs.

These creatures, thus anatomically allied to aquatic and aërial beings, are called *amphibious;* because being possessed of both gills and lungs, they can respire equally well in air and water, as circumstances may require. In addition to these many other species have been very generally esteemed amphibious; as, for example, *otters*, *seals*, *frogs*, and *lizards*, but it is now ascertained that they can breathe air only, and when they descend into water, do so merely for the sake of procuring food. Blumenbach observes that *water-newts*, when placed in a deep vessel filled with

water, are seen to rise frequently into the air in order to breathe; and it is well known to fishermen that *turtles* cannot continue beneath the surface for any considerable length of time.

With the exception of the *batrachia*, reptiles inspire air alone, and can, therefore, only breathe with lungs. These organs are, however, at first very simply constructed. In place of consisting of a great number of cells, connected together by cellular substance, and enclosed within one common envelope, as they appear in the Mammalia, they are merely large bags or sacs, lined with a very vascular membrane, into which air is alternately admitted and expelled through a trachea, or air tube, which communicates with the mouth. In the *aphidia* this air-tube opens into the bag by a single orifice. In the *crocodile* it divides into bronchi before reaching the lung; and in the *turtle* each bronchus penetrates the substance of the lung to its remotest point.

It has been already stated, that in the *cephalopoda* the branchiæ are enclosed in a bag, very similar to this pulmonary sac, or rudimental lung; and that in the *siren* the branchiæ and the bag are separated, and placed in different parts of the body. Here the branchiæ are entirely removed, and the bag alone remains; so that the steps are slow but obvious, by which organization rises to maturity. The lung of a *salamander* is exactly like the branchial bag of the cephalopoda, after the branchiæ have been removed. In the *colubes natrix* the same structure is preserved, with this exception, that the bag is larger in proportion, and that the internal surface of its anterior half is beautifully reticulated like the interior of the second stomach of ruminating mammalia. This appearance may be regarded as the first attempt at the division of the sac into cells. In the lungs of a *frog* these cells are very evident, and in the *turtle* they are numerous and large. *Serpents* have only a single sac or lung, which extends from the œsophagus to the lower margin of the liver; the *siren lacertina* has two, which stretch to the end of the abdominal cavity, and in the *cameleon* they are so large, that this creature can, by inflating them, swell itself up to an amazing size. Reptiles, in this respect, differ from all other animals. In birds and the mammalia the air-cells of the lungs are small but numerous, and well adapted for the reception of air; their lungs are compact and of moderate size, but amply supplied with blood. The lungs of reptiles, however, are large, floating, and unconfined among the viscera of the abdomen; divided into few cells. and scantily furnished with vital fluid (*fig* 66, *f*, *f*.) This difference of respiratory

Fig. 66.

The Lungs of a Frog. *a a*, the liver; *b*, the spleen; *c*, the stomach; *d*, the intestines; *e e*, the heart; *f f*, the lungs.

apparatus between reptiles and warm-blooded animals is partly accounted for by the difference of their circulating functions. In the latter all the blood must be passed through the lungs, and must be purified by the air before it can circulate through the body; while in the former not more than one-third requires to be subjected to such an ordeal.

Before leaving the subject of respiration among cold-blooded animals, we cannot refrain from a few remarks upon the wisdom with which the deficiencies of one function are compensated by the greater developement of another. Thus, in fishes all the blood passes through the gills before it circulates through the system; while in reptiles a portion only is sent for purification to the lungs. The influence of these different arrangements, however, upon the blood is not so great as at first view might be imagined. These two classes of beings inhabit very different elements. The skate breathes in water, the frog breathes in air; the blood of the one is freely exposed to the purifying principle, that of the other is acted upon by it only through the instrumentality of an inconvenient medium. While, therefore, only a portion of the blood in reptiles can be purified

during each circulation, seeing that a portion only is exposed to the purifying principle, the blood in fishes can also be only partially purified during each circulation, since it is exposed to a medium which is only partially qualified for that purpose. In the one case there is an imperfect circulation, in the other an imperfect respiration; and since it must be a matter of little moment whether ten ounces of blood be only half purified, or the half of ten ounces be wholly purified, the ultimate effect of this difference of arrangement in these different animals must be very much the same. The perfection of the medium in which reptiles live compensates for their pulmonary circulation being partial; and the complete pulmonary circulation of fish compensates for their imperfect medium. Both classes of animals circulate blood alike cold, and execute functions alike tardy.

The respiration of *birds* is distinguished by many interesting peculiarities, (*fig.* 67.) Formed with wings and other organs for the purposes of flight, the loose and ponderous lungs of reptiles would have been highly incommodious; and possessed of a double heart for conducting a double circulation, such a respiratory apparatus as could expose a sufficient quantity of blood to a sufficient quantity of air was indispensable.—Means have been accordingly employed for the attainment of these objects.

Fig. 67

Lungs of the Ostrich. *a*. the heart; *b*, the stomach; *c*, *c*, the intestines; *d*, the trachea; *e*, the lungs; *f f f*, air-cells, in which are also seen the tubes by which these air-cells communicate with the lungs.

To prevent the inconveniences of motion, the lungs are not free, but fixed; not allowed to float without restraint in the cavity of the chest, but niched down between the ribs on each side of the dorsal spine. And to ensure the full arterialization of the blood, without interfering with the natural habits of the animal, air is allowed to every organ, and respiration is carried on in every part. In addition to two solid and fleshy lungs, which are firmly fastened down between the intercostal spaces in the back part of the chest, there are sacs or bags of considerable size, not unlike the lung of a salamander, scattered over the other viscera of the abdomen, which communicate with the lungs and with each other, are formed to contain air, and fill and empty as the bird inspires or exhales. Similar air-cells exist externally between the muscles; the bones themselves, which in the mammalia contain marrow, are in birds filled with air; and it is a remarkable fact, that the quantity of air which they individually contain is proportioned to the influence which they exert on the loco-motion of the body. Thus, in the *eagle* and other birds of flight, the bones which support the wings are filled with air; while in such as the *puffin*, whose wings are unequal to any lengthened flight, or the *ostrich*, which prefers to run, air-cells are found in greatest numbers within the bones of the leg and thigh.

The manner in which these pneumatic cavities communicate with the proper lungs of the bird, is very simple. When the trachea enters the lungs, it divides into many branches. Some of these are wholly expended upon the texture of these organs, while others, without giving off any branches in their course, proceed directly to the surface of the lung, upon which they terminate by open mouths. These air-holes, or branchial apertures, are covered by some of the air-cells which surround the lungs; these air-cells open into others, and thus a free intercourse is established with every part of the system; so that the air which enters the lungs by the trachea from the fauces, can pass out of them through the air-holes upon their surface into the air-cells, whether they lie within the bones, among the muscles, or in the abdomen.

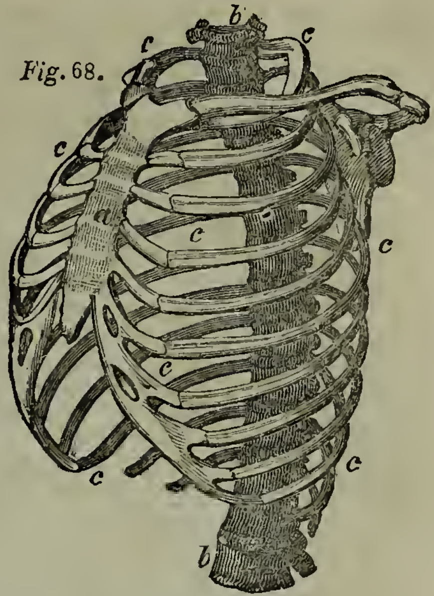
The beauty of this contrivance is equalled only by its importance. Independently of a perfect supply of air being thus furnished at all seasons, for the purposes of respiration, without any inconvenience to the general system, the relative weight of the body is materially diminished, the difficulty of breathing in a very rarified atmosphere is counteracted, and the necessity of a frequent respiration during rapid flight may be dispensed with. It is also probable, that while on wing, birds can rise or fall at pleasure, by filling or emptying their air-cells, as fishes do by inflating or collapsing their air-bladder, and it has been conjectured by Mr. Hunter, that these cells are in some degree connected with their musical faculty.

In the *mammalia*, this function attains its most perfect state. Into the construction of their pulmonary system every anatomical and physiological advantage has been introduced which could render it complete; the superior mechanism of their lungs, the number of their air-cells, the minuteness of their blood-vessels, their position within a case which can contract and dilate at pleasure, and the variety of means which are employed to fill and empty them with air, while they themselves continue passive,—these and many other circumstances, which will hereafter receive farther notice, indicate the anxiety which has been displayed to endow this class of beings with a respiratory apparatus worthy of working in connection with that admirable circulating system which they enjoy, and which has already been described. But, without premising any additional remarks upon the respiration of the mammalia generally, we shall at once proceed to explain it as it appears in man, and with this view shall, in the first place, briefly describe its anatomy, secondly, its mechanism, thirdly, its theory, and lastly, its effects.

Anatomy of the Pulmonary System.

The thorax or chest is a conical cavity, (*fig.* 68,) the apex of which is formed by the neck, and the base by a muscle called the diaphragm, which separates it from the abdomen. Externally it is protected by bone; on the front by the breastbone, (*fig.* 68, *a*); behind by the spine or backbone (*fig.* 68, *b*, *b*), and on each side by the ribs (*fig.* 68, *c*, *c*, *c*, *c*.) These bones are connected by ligaments and joints, and give attachment to muscles which serve to regulate their motions. Within, it is

Fig. 68.



Trunk of the Human Skeleton. *a*, the sternum or breast-bone; *b b*, the spine; *c c c c*, the ribs.

divided by a lining membrane called the *pleura* into three large compartments, independent of several smaller and less important cavities. In the largest of these is contained the right lung, in the smallest the heart, and the left lung lies within the third compartment (*fig.* 75, *a*, *b*, *b*.)

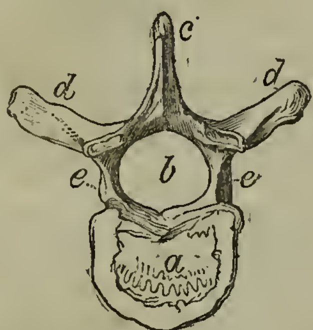
All the parts concerned, therefore, in the respiration of man may be arranged into three divisions. First, the bones which form the respiratory cavity; secondly, the muscles by which these bones are moved and the size of the cavity regulated; and thirdly, the respiratory organs contained within the cavity. Belonging to the first division are the sternum or breastbone, twelve dorsal vertebræ, and twenty-four ribs. Several pairs of muscles, and the diaphragm, constitute the second division; and the trachea, larynx, and lungs are comprehended by the third.

Between the anterior extremities of the ribs and situated over the heart, lies the *sternum*, or breastbone. (See *fig.* 68, *a.*) It is a light and spongy bone, depending principally for its strength upon the numerous ligaments which cover it. In the child it is divided by cartilaginous partitions into eight pieces, which, as life advances, are reduced to three, and in old age are united into one. Its lower end gives rise to a sharp-pointed cartilage which lies over the stomach and may be felt externally: its upper end is somewhat hollowed in the middle, to allow

the trachea or windpipe to pass under it; and on each side there are seven oval depressions for admitting the cartilaginous extremities of the first seven ribs. The connections and situation of the sternum prevent it from having any motion of its own; it therefore follows to a certain extent the movements of the ribs to which it is articulated.

The *spine*, or what is vulgarly called the backbone, (*fig.* 68, *b, b*,) is composed of twenty-four very irregular bones, which are separated from, yet connected with, each other by as many intermediate pieces of cartilage. These bones are called *vertebræ*, and the cartilages which connect them are styled from their position *intervertebral cartilages* (*fig.* 69.) These twenty-four

Fig. 69.



A dorsal Vertebra. *a*, body of the vertebra; *b*, the canal for containing the spinal marrow; *c*, the spinous process; *d d*, the transverse processes; *e e*, the articulatory processes.

vertebræ are arranged into three classes; the cervical, dorsal, and lumbar vertebræ. The first seven are the cervical, because they belong to the neck; the next twelve are the dorsal, because they belong to the back; and the last five are the lumbar, because they are situated in the loins. Peculiarities of form as well as of situation, distinguish these different orders, but as a knowledge of the dorsal vertebræ will be sufficient for our purpose, the present description will be confined to them. Each of the twelve dorsal vertebræ consists of a body, four articulating processes, two transverse processes, and one spinous process. The *body* is formed of soft and spongy bone, which is circular before, flat towards the sides, hollowed out behind into a crescentic shape for containing the spinal marrow, and somewhat concave both above and below for the accommodation of the intervertebral cartilage. Situated laterally on the body of the vertebræ, are the four *articulating processes*; each vertebra being connected with the two immediately adjoining it. Two of these processes are situated near its upper surface to articulate with corresponding processes belonging to the vertebra above, and two are placed near its under surface to join with those of the vertebra below. The two superior articulating processes of one vertebra are thus connected with the two inferior articulating processes of another, and these points of union not only co-operate with the intervertebral cartilages in keeping these two vertebræ together, but permit a slight rotatory motion of the one upon the other. The *spinous process* projects directly backwards from the body of the vertebra, and may be felt externally by moving the finger along the spine; while the two *transverse processes* stand out on either side, and have the ends of the ribs attached to them.

The *ribs* (*fig.* 68, *c, c, c, c*) are twelve long, curved bones, which are joined behind to the dorsal vertebræ, and before to the sternum, or breast bone. The upper seven are called true ribs, because they are immediately connected to the sternum; the lower five, false ribs, because they are implanted into each other by cartilaginous appendages, and are only supported by the sternum through the medium of those above. They are concave internally, that the lungs may have more space to expand; externally convex, that their arched form may enable them more effectually to resist external injury; and they are attached to the spine at an acute angle, that they may not be moved out of their ordinary position without enlarging the dimensions of the chest. The *head*, or vertebral end, of each rib is so articulated with the spine, as to be fixed upon the intervertebral cartilage, and is connected on each side with the vertebræ which this cartilage separates. About an inch from this head there is a small bump upon the back or convex surface of the rib, which articulates with the transverse process of the vertebra below, and a little above this bump there is a second, to which strong ligaments are attached for the surer connection of the rib and vertebræ. The anterior or sternal ends of the ribs are not bony, but cartilaginous. The cartilaginous extremities of seven of them are jointed to the sternum by regular sockets or small oval cavities, and the other five are implanted into each other.

The motions allowed by these articulations are limited, but sufficiently ex-

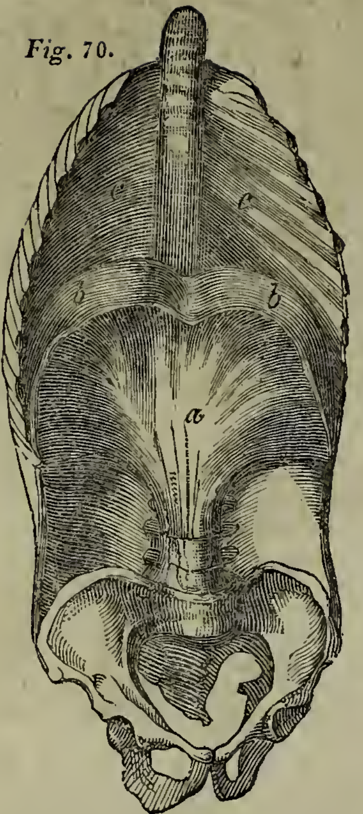
tensive for the purposes of respiration, when in a healthy state. During inspiration the chest expands for the reception of air, and during expiration it contracts to expel air which is no longer useful. Two motions, therefore, are all that can be required—an upward and an outward motion. The distance between the spine and sternum is increased by the former, that between the ribs by the latter. Now these two motions, and only these, are performed by the ribs, and their articulations are such that they cannot execute one of these movements without the other. By their sternal ends they can rise and fall, because the sternum, into which they are articulated, is a moveable bone, and depends for its movements upon the motions of the ribs; and by their vertebral ends they can move outwards as their sternal ends rise. But their sternal ends cannot rise unless their vertebral ends rise also; and their vertebral ends cannot rise without pushing the sternum out, and thus increasing the short axis of the chest in every direction. Had they been articulated at right angles with the spine, the size of the chest must have been diminished, whether they rose or fell. But as their oblique position is their natural state, they cannot rise without moving outwards, and they cannot move outwards without increasing the capacity of the thorax. During inspiration, therefore, the chest must be expanded, and during expiration it must contract; and these are the two conditions required.

All the *muscles* which surround or are in any way connected with the bones which have been now described, do occasionally contribute in assisting the function of the lungs. Haller informs us that, while labouring under rheumatism of the large muscles of the chest, his respiration was difficult; and it must have been observed by every one, how the arms are fixed and the shoulders raised, when our object is to procure a very full inspiration. But the muscles more especially intended for respiratory organs are the *Serrati Postici*, *Triangularis Sterni*, *Intercostales*, and *Levatores Costarum*. The origins and insertions of these muscles a general reader would feel little interest in perusing, their actions only it is his business to understand. It may be sufficient, therefore, to observe that, with the exception of two,—one of the Serrati and the Triangularis Sterni,—all these muscles are employed in elevating the ribs during the process of inspiration; so that nature might, at first sight, appear more anxious to provide an efficient inspiratory, than expiratory apparatus. But this is not really the fact. For when it is considered, that the natural condition of the chest is that which obtains after a full expiration, it will be obvious that the elasticity of the cartilages of the ribs and of the ligaments, which join them to the sternum and the spine, must form a powerful expiratory agent, and must tend, as soon as the muscles of inspiration have relaxed, to reduce the chest to its natural state. The bones, which form the walls of the chest, and the muscles, which cover these bones, may thus be regarded as antagonizing powers. The first are organs of expiration in virtue of their physical connections; the last are organs of inspiration in virtue of their specific action. When the ribs are permitted to follow their natural tendency they fall; but when the intercostales are allowed to act they rise. Natural position secures the one state, vital action the other.

There is still, however, another way in which the dimensions of the chest might be further modified. When the ribs are elevated, the distance between the spine and sternum is increased; when depressed, it is diminished; but we have as yet seen no mechanism which can alter its long diameter, which can either extend or abridge the distance between its base and apex. This brings us to the *Diaphragm* (*fig.* 70, *a*), a muscle of much greater importance than any yet described; which, being peculiar to the mammalia, distinguishes the respiration of that class from every other; and which is so situated as to divide the interior of the body into two parts—the chest and the abdomen.

The diaphragm is generally spoken of as composed of a central tendon and two muscles; the greater of which arises from the inside of the breastbone and cartilages of the false ribs, and the lesser from the vertebræ of the loins. But it is more simple to view it as a single muscle, which is fleshy at the circumference, and tendinous at the centre; as arising from the ribs above, and from the spine below; and as having the fibres issuing from these two origins inserted into a tendon, which, from its use and position, forms their common centre. This heart-shaped

Fig. 70.



The Diaphragm during Expiration. *a*, its tendinous centre; *b b*, its fleshy sides; *c c*, the lateral cavities of the chest, in which the lungs lie.

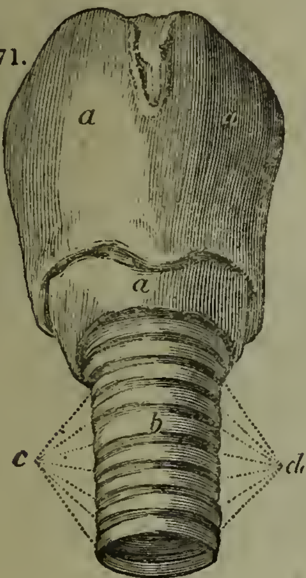
tendon gives passage to the inferior vena cava from the abdomen into the chest, and also to the œsophagus from the chest into the abdomen. It is firmly attached to the pericardium; so that the centre of the diaphragm being fixed, motion must be limited to its fleshy sides; and from the nature of their origin it may be inferred, that these muscular wings are concave towards the abdomen, and convex towards the chest.

As it is by means of this muscle that respiration is principally conducted in man, everything has been done which the obliquity of its position, the nature of its attachments, and the mode of its construction could afford, to confer upon it the greatest range of motion with the least possible expenditure of space, or power. Why, may it be asked, should it not have been passed directly across the body from the sternum to the dorsal spine, in place of being made to slant from the loins to the sternum? Why should it be concave towards the abdomen, and convex towards the chest? Why should it, in opposition to all other muscles, be tendinous in the centre, and fleshy at the circumference? And, finally, why should its sides be left free and floating, while its middle is firmly bound to the pericardium? Nature seldom shews any marks of peculiar design, without having some peculiar design in view; nor does she deviate from her general plan, without having something to accomplish which a particular arrangement only could effect. Had the diaphragm been passed directly across the body from the sternum to the spine, that is, had it assumed the form of a transverse plane, its motions could not have had such an influence upon the dimensions of the chest, as they have since it is placed obliquely. When it contracts during inspiration, a considerable portion of the abdomen is, as it were, thrown into the chest; and when it relaxes during expiration, a considerable portion of the chest is again made abdomen. But had the wings of the diaphragm been concave towards the chest, the space gained by their contraction would have been taken from the chest, and given to the abdomen; the very reverse of what was required. Again, had not the centre of the diaphragm been tendinous, the vena cava and œsophagus, which pass through it, must have been compressed whenever it contracted; and had not that centre been fixed, a muscle of such size and range of movement as the diaphragm, could not have worked with any certainty or effect. Besides, as the lungs are placed in the lateral cavities of the chest, and the heart occupies the centre, the lateral portions of the diaphragm only could influence the size of the respiratory organs; so that it had been, in one sense injurious, and in every sense useless to have endowed its centre with muscularity. The position of the diaphragm, therefore, is oblique to increase its range of motion; its sides are muscular to enable them to contract; concave towards the abdomen, that when contraction reduced them to a plane with the central tendon, the space then gained might be in favour of the chest; its centre is tendinous for the insertion of the muscular wings, to enable these wings to contract more forcibly, and to give a safe passage to the vena cava and œsophagus; and that centre is attached to the pericardium, that during the contraction of

the wings there may be a fixed point to give direction to their movements.

The *trachea*, or windpipe, is an almost cylindrical tube, composed of cartilaginous rings connected to each other by ligamentous substance, with which muscular fibres appear to be intermixed, and covered internally with a soft and vascular membrane, which secretes a mucous fluid to defend the surface of the canal from the acrimony of the air, (*fig.* 71.) For the accommodation of

Fig. 71.



Anterior View of Larynx and Trachea. *a, a, a,* anterior view of cartilages of larynx; *b,* trachea; *c,* cartilaginous rings of trachea; *d,* ligamentous and muscular portions of the trachea, by which the rings are connected.

the œsophagus or gullet, which lies immediately behind the trachea, (*fig.* 72, *e*) these cartilaginous hoops do not encompass the entire tube, but terminate posteriorly in a membrane, partly ligamentous and partly muscular, which, while it completes the trachea, admits of compression, and thus presents no inconvenience to the passage of the food along the œsophagus (*fig.* 73.)

On the top of the trachea is mounted the *larynx*, or musical part of the windpipe; which is composed of two portions —the *glottis* and *epiglottis*. The glottis is formed by the conjunction of four pieces of cartilage; *fig.* 72, *c, c, c,* represents a posterior view of these cartilages; and *fig.* 71, *a, a,* an anterior view of two of them, which are lined with the same mucous membrane that coated

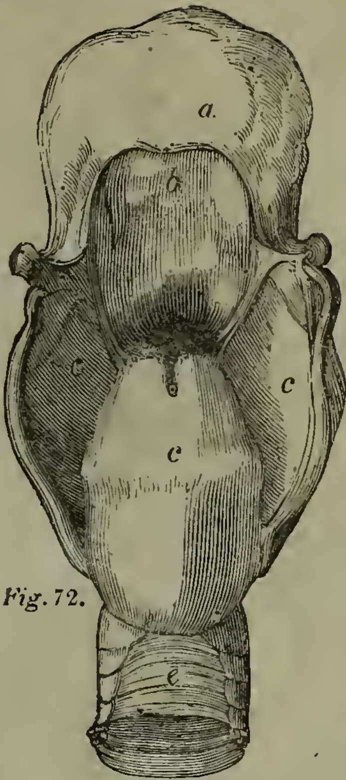


Fig. 72.

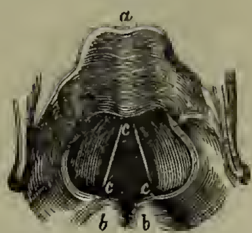
Posterior View of Tongue, Larynx, and Trachea *a,* the tongue; *b,* the epiglottis; *c, c, c,* other cartilages of the larynx; *d,* opening into the cavity of the larynx; *e,* posterior portion of the trachea, which is not cartilaginous but membranous, consisting partly of ligament and partly of muscular fibre, in its natural situation in contact with the œsophagus.

Fig. 73.

Represents the effect of the movement of the tongue backwards on the mechanism of the larynx, in the act of deglutition. *a, a,* the tongue; *b,* the morsel of food arrived at its back part or base, and already beginning to force down, *c,* the epiglottis, over the opening *d* into the glottis, and so closing the aperture.

the trachea, and are covered with small muscles which serve to move them. The epiglottis (*fig.* 72, *b*) consists of a single cartilage, which is situated above the other four, and, like the key of a flute, can close or open the *rima* of the glottis or longitudinal aperture through which the air passes into and from the lungs (*fig.* 74.)

Fig. 74.



c c c, margins of the glottis cut open and folded back, b b the vocal chords, in the site of the rima glottidis; a, the epiglottis.

After the trachea has descended the neck and entered the thorax, it divides into two parts, one of which goes to each lung. The ramifications which arise from these primary divisions of the windpipe are styled *bronchi*, and resemble exactly the air-tubes of insects both in construction and office. As these bronchi proceed they become smaller, and as they become smaller the cartilaginous rings of which they are composed become less distinct, until at length they entirely disappear; so that the air-cells, in which they ultimately end, appear to consist of nothing but an extension of the mucous membrane which had lined the bronchi.

The *lungs* (*fig.* 75, *bb*) are two spongy, conical bodies situated within the two lateral cavities of the chest, and separated from each other by the heart and a strong

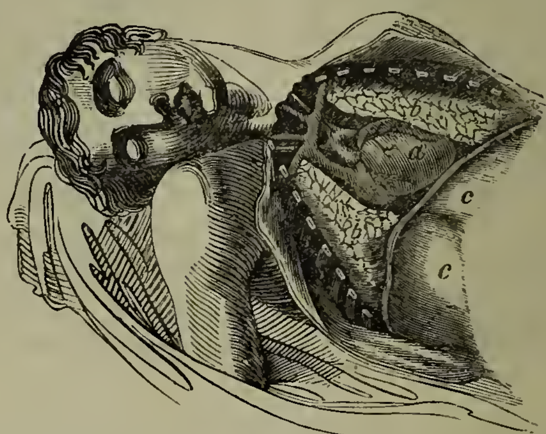


Fig. 75.

The Lungs of Man.—*a*, the heart; *b b*, the lungs; *c c*, the diaphragm.

membranous partition (*fig.* 75, *a*.) They are covered anteriorly by the ribs and sternum, behind by the spine, and their base rests upon the diaphragm, which separates them from the abdomen. In consequence of their containing air, from which they never can be cleared after birth, they are the lightest viscera in the body, floating upon the surface when placed in water. Their external aspect varies with their age. In infancy they are of a pale red, in youth of a darker colour, and in old age of a livid blue. They are distinguished into parts called *lobes;* and as the right side of the chest is larger than the left, because the heart is principally in the left side, the right lung possesses three lobes, while the left has only two. These lobes are composed of *lobules* connected by cellular substance, and these lobules consist of an intermixed congeries of air-cells and blood-vessels. With the exception of a few nerves and lymphatics, which they have in common with every other organ, the lungs are entirely made up of air-cells, blood vessels, and cellular tissue. The last substance, which is the smallest in quantity, serves merely to connect the other two: and when it is entirely removed, after injecting the air-tubes and blood vessels with sealing-wax, the volume of the lungs is very triflingly diminished.

From the sketch which has been drawn of the comparative anatomy of respiration we have seen sufficient to prove, that what is principally required in the respiratory apparatus, is an organ so constructed as to allow the largest possible quantity of deterio-

rated blood to enjoy the fullest intercourse with the largest possible quantity of vital air. Such an organ is the grand desideratum of the function; every other is preparatory and subservient; and such a place of intercourse is met with in the human lungs. It has been supposed by Hales, that, representing the size of each air-cell at $\frac{1}{100}$th part of an inch in diameter, the amount of surface furnished by them collectively would be represented by 20,000 square inches. Keil has estimated the number of these cells at 174,418,615, and the surface which they present at 21,906 square inches; and Lieberkuhn has increased it to no less than 1500 cubic feet. It is upon these air-cells that the venous blood is distributed by an infinity of vessels derived from the pulmonary artery; it is for the sake of these air-cells that the lungs are formed, and the extensive respiratory machinery, which has been now described, is erected; it is during the circulation of the blood upon these air-cells that the desired alterations in its properties are wrought; and when the relative extent of the actual respiratory organ is compared with the insignificant dimensions of the lungs in which that organ is contained, it is difficult to conceive how so small a part, differently constructed, could be more effectually adapted to the objects which it is intended to accomplish. A stratum of blood, several hundred feet in surface, is exposed to a stratum of air still more extensive; and these two strata of contiguous fluids are comprehended within an organ, which may be easily compressed within the compass of a few inches. To look for any parallel to this amid the most masterly contrivances of science were vain.

Mechanism of Respiration.

There is as great variety in the *mechanism* as in the apparatus of respiration. Two classes of animals do not breathe in the same way, and different orders of the same class are not unfrequently distinguished by individual peculiarities. When the *frog* inspires he shuts his mouth, draws a quantity of air through his nostrils into the large membranous bag which is attached to his under jaw; this bag contracts, and the air which it contains is forced down into his lungs (*fig.* 66.) When the purposes of inspiration have been served, the muscles of the abdomen contract, his lungs are compressed, and expiration is performed. This animal, therefore, swallows the air which he respires as he does the food which he digests; and the most effectual mode of suffocating him is to keep his mouth open.

When the *trout* respires it opens its mouth and takes in a quantity of water; the mouth is then shut and the inclosed water is forcibly driven among the vascular laminæ of its gills. During the passage of the water through these fimbriated organs, the air which it contains exerts its purifying influence upon the blood, and, after accomplishing its object, it escapes beneath the large scales by which the gills are covered. In many worms and flat fishes the water, thus admitted by the mouth, is expelled through small holes situated in different parts of their body, but more especially in their sides. Fishes, therefore, cannot inspire air unmixed with water, nor can they inspire water unmixed with air. Air is necessary as the vitalizing principle of their blood, and water is necessary as a vehicle for the proper application of this principle to their blood vessels.

In *birds* the lungs are so nitched down between the ribs and perforated by air-holes, that they can neither expand as the chest enlarges, nor collapse as it falls. They preserve unalterably the same size. When the bird inspires his chest is elevated, a vacuum is formed within and air rushes into the lungs. But as it cannot remain in them, in consequence of the air-holes upon their surface, it passes out into the abdominal cells. Expiration now begins, the ribs fall, the air in these large air-cells is compressed, it again enters the air-holes, passes a second time through the lungs, and is expelled through the wind-pipe. The lungs of this class, consequently, contain a mere fraction of the air which they inspire, and during expiration they are compressed, not immediately by the ribs, but mediately through the air-cells which surround them.

In *man* respiration consists of a succession of alternate acts by which air is received into and removed from the lungs. When it is received the act is called *inspiration;* when expelled *expiration.* The one process depends upon the other. Air cannot be expired until it have been inspired, and a second inspiration cannot be made till the air already taken in have been expired. But, although these two processes are thus connected, one of them

is a much more vital action than the other. The lungs cannot be filled with air without a considerable effort on the part of many living agents; but they may be emptied of it in virtue of the physical construction of the respiratory system. A knowledge of this system is sufficient to prove that the natural state of the lungs is that of collapse. The ribs are jointed so obliquely to the vertebræ, and so connected anteriorly to the sternum, that a considerable force is necessary to bring them to right angles with the spine; that is, into a state prepared for inspiration. After death, therefore, when every living principle is extinct, and the body is allowed to fall into its natural attitude, the state of the chest is always that of expiration. The ribs are depressed, the diaphragm is pushed up into the thorax, and the lungs are confined within a cavity which expiration has diminished to the utmost.

It is obvious that as long as this state of parts continues, the entrance of air into the lungs is impracticable. But it is equally evident that, if by any means the chest could be enlarged and the lungs expanded, a vacuum would form within the thorax, the size of which would be proportional to the extent of this enlargement. Now, this actually occurs, and we have examined the machinery by which it is accomplished.

A short time, say one second and a half, after expiration, the muscles of inspiration begin to act. The intercostals contract, and by elevating the ribs increase the distance between the spine and sternum. The diaphragm descends as the ribs rise, and by pushing down the abdominal viscera allows the lungs greater freedom for expansion in that direction. Thus the cavity of the thorax is enlarged on all sides, and, since the lungs are quite passive during all these changes, diminishing when compressed and expanding when liberated, their dimensions must now be greatly enlarged, the air which they contain considerably rarefied, and a vacuum of some extent must be formed within their air-cells. But as air is an elastic fluid which seeks its own balance wherever situated, and as the air within the chest is rarer than that without, the consequence is that the denser or external air will, in virtue of its greater gravity, enter the trachea through the nostrils and mouth, and descending into the lungs occupy this newly-formed vacuum. This influx of denser air will continue until the density of the internal be equal to that of the external air, when the act of inspiration is at an end. The intercostal muscles now relax, and allow the elasticity of the ribs, which had been hitherto counteracted by the contraction of these muscles, to restore them to their natural position. The diaphragm likewise relaxes, and allows the abdominal muscles to re-act and thrust it up into the cavity of the chest. The lungs are thus encroached upon in every direction; before by the ribs and sternum, behind by the ribs and spine, and below by the diaphragm. The newly-admitted air which they contain, being now no longer in a state of equilibrium with the external atmosphere, is forcibly expelled, and the chest is restored to the same condition in which we found it.

Such is the mechanism of respiration, as it obtains in a state of health, and the reader cannot fail to perceive how parts, the most distant and different in action, are made to co-operate to the production of the same effect.

In ordinary breathing we respire almost exclusively with the diaphragm, the motion of the ribs being scarcely perceptible. Dr. Jentz saw a man in Paris, who permitted an anvil, weighing 600 lbs., to be placed upon his chest while he lay in an horizontal posture, and a bar of iron to be beaten out upon it with weighty hammers, without discovering symptoms either of pain or uneasiness. But when, from debility or disease, the ordinary respiratory organs are insufficient, or when, from over-exercise or temporary excitement, the lungs require an unusual quantity of air, nature has several auxiliary resources in reserve.

If an inspiration only somewhat fuller than usual be desired, the *serrati levatores, triangulares, and pectoral muscles* are brought in to co-operate with the intercostals in elevating the ribs. But if the very fullest inspiration which can be taken be necessary, the bones forming the shoulder and shoulder-joints are firmly fixed by resting the hands upon the knees, and all the muscles, which have the slightest connexion with the chest either before or behind, are added to the inspiratory apparatus. At the same time, the abdominal muscles are relaxed to the utmost to facilitate the ascent of the ribs, and the diaphragm is, for the same reason, enabled to contract to the utmost to increase the long axis of the chest. In this way,

twice the usual quantity of air can be taken into the lungs at a single inspiration. But as the chest has been brought by this extraordinary effort into a very unnatural state, as all its ligaments and cartilages have been strained, and every neighbouring muscle has been pressed into its service and contracted to the utmost, it follows, that as soon as inspiration terminates there will be an increased tendency in the chest to resume its ordinary size—a tendency commensurate in degree with the force of the previous inspiratory effort. The farther the ribs were carried out of their natural direction the more certainly will they return to it when the forcing power has ceased to act, and this strong expiratory tendency on the part of the ribs is powerfully aided by the strong contraction of the abdominal muscles, which, by pressing the diaphragm far up into the chest, shortens the long axis of the thoracic cavity, as much as the falling of the ribs diminishes the short one.

The first Inspiration.

To a certain extent the respiratory apparatus is subject to the will. If a full inspiration be desired, we can call every inspiratory organ into action, and we can expand the chest to its utmost size; or, by forcing down the ribs and pushing up the diaphragm we can compress the lungs with unusual force, and expel from them a greater quantity of air than ordinary. But this controlling power which we possess is very limited, and the muscles of respiration are neither at all times obedient to the will, nor do they require the stimulus of the will to bring them into exercise.

When, by a forced inspiration, we have taken into our lungs the largest possible quantity of air, no mental effort can enable us to preserve the chest in that elevated state beyond a certain period. The intercostals will relax, the diaphragm will ascend, and the ribs will fall. Or when, by a forced expiration, we have expelled from the lungs the largest possible quantity of air, and have reduced the chest to its smallest size, inspiration soon commences even in opposition to the will, and, overcoming the elasticity of cartilages and the resistance of position, the ribs rise and liberate the lungs.

From the physical circumstances with which the child before birth is surrounded, it is evident that respiration is incompatible with its economy. Excluded from air in a separate state, and enveloped in membranes filled with a watery fluid, the fœtus, or unborn child, is virtually an aquatic animal, must be adapted to an aquatic life, and must be nourished with blood which comes to its system already purified for the purposes of life. To support a respiration of its own were consequently both impracticable and unnecessary. As long, therefore, as it is connected with its mother's system, its lungs cannot act through want of air, and its blood is arterialized without these organs; but the moment at which this connexion is dissolved by birth, the child is wholly cast upon its own resources, a double circulation is established, and respiration begins.

The first respiratory act appears to be purely mechanical, resulting from the change of position which the child undergoes at birth. By referring to the adjoining figure, which represents the child as it lies in the womb, it cannot escape remark, that everything has been

Fig. 76.

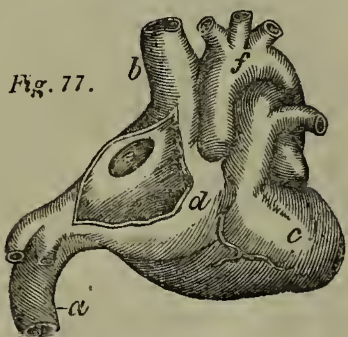
done which position could effect to diminish to the utmost the dimensions of the chest; and a little consideration must convince us that any change from this position, it matters not in what direction or to what degree, will have the effect of liberating the lungs from a portion of the pressure which they bear. The head cannot be raised from the breast, nor the knees removed from the abdomen, without straightening the spine, and the spine cannot be reduced to a straight line without elevating the ribs, and permitting the abdominal vis-

cera to fall; but the ribs cannot rise, nor the diaphragm descend, without enlarging the chest, and as the chest enlarges, the lungs, which are the most elastic organs of the body, will expand, their air-cells, which had been hitherto collapsed by external pressure, will assume an open form, and the external air will, in obedience to its own principles, go where it meets with the least resistance.

Connexion of the first Inspiration with the Establishment of a Double Circulation.

The same cause which accounts for the first introduction of air into the chest, is likewise adequate to explain why the double circulation and respiration in the child are cotemporaneous in their commencement. The blood, which during fœtal life had passed through the oval hole *e*, between the auricles, into the left side of the heart, and through the arterial duct into the aorta, *f*, without visiting the lungs, is now solicited out of its ordinary path by the expansion of the chest.

Fig. 77.



a, inferior vena cava; *b*, superior vena cava; *d*, right auricle; *e*, foramen ovale; *f*, aorta.

The same vacuum which forms within the lungs during this expansion, will draw blood through the pulmonary artery as forcibly as air through the windpipe. The arteries of the lungs will, therefore, fill with blood as their air-cells fill with air, and the moment the establishment of a double circulation requires that the child should purify its own blood is also the moment that respiration begins. Were not the lungs relieved from an unusual degree of pressure by birth, as we have endeavoured to prove, or did not something equivalent to this happen during that eventful period, to make the passage of the blood through the lungs easier than through the arterial duct and oval hole, we are left without a reason for the sudden obliteration of these two fœtal passages, and for the new and circuitous route taken by the venous blood at birth from the right to the left side of the heart. But, supposing that such a change obtains at the moment of birth, and that the air-tubes of the lungs and the arteries simultaneously expand, every difficulty vanishes. The blood will then find a more open passage through the pulmonary artery than through the aorta, the arterial duct being little required will gradually contract and ultimately close, the receipt of the left auricle equalling that of the right, the pressure against the opposite sides of the auricular partition will be equalized, the valve of the oval hole will be pressed up against the margins of this communicating aperture, and a perfect pulmonary circulation will be established. But, while these changes are going on within the sanguiferous system of the lungs, their pneumatic apparatus is at work; fresh air is drawn in at every inspiration, the passing current of deteriorated blood is subjected to its influence, and the common object of both functions,—the conversion of this vital fluid from a venous to an arterial state,—is effected by a common cause.

The beauty of this simple arrangement is very striking, and the indissoluble connexion between the action of the lungs and heart is remarkably displayed. As long as the blood of the fœtus is purified by the mother, a single circulation is sufficient; but when birth cuts off the child from every adventitious aid, and casts it upon its own resources, its lungs, which had been hitherto inactive, are now called into operation, its blood is made to undertake a second journey to acquire those vital properties which formerly it had obtained elsewhere, and the same cause, which fills the blood-vessels of the lungs with blood, is employed to fill their air-tubes with air, prepared for its purification.

Effects of Respiration.

It may be inferred, then, that one of the first and most important effects of respiration is exerted on the circulating blood; but there is abundant evidence to show, that many other effects of no slight moment are accomplished by this function. The necessity of air for the support of animal life could scarcely escape observation in any age; but the ancients being ignorant both of the

constitution of the atmosphere, and of the alterations which the air experiences while in the lungs, could form no rational conjecture of the ends it serves in the economy; accordingly, there is no extravagance of the imagination in which they did not indulge. Without any further notice of these opinions, we shall go on to state what the uses of this function really are, as far as they are ascertained.

Effects of Respiration on the Chemistry of the Air inspired.

COMMON atmospheric air is composed of three gases, which are combined in different proportions, and are endowed with different properties. The most abundant of these is called *azote*, a term which signifies, 'incapable of supporting life;' the most useful is *oxygen*; and *carbonic acid* is the third, which amounts to little more than one per cent. of the whole.

For a long time it was believed, that upon the first of these gases—*azote*, respiration exerted little, if any, influence. It was regarded rather as a vehicle for the conveyance of oxygen to the lungs, than as a substance gifted with any intrinsic virtues. Subsequent observations have ascertained, however, that it disappears during respiration in considerable quantity: since some object must be contemplated by its removal, it is now generally considered that it acts some part in the economy of this function more efficient than that of affording a convenient vehicle for oxygen, although we are wholly ignorant of its real use. Sir H. Davy respired 18 cubic inches of common air during one minute. Before the experiment this air was found to contain 9.3, and after it only 4.1 cubic inches of azote, shewing that 5.2 cubic inches had disappeared. This experiment was variously repeated with the same result, and its accuracy has been subsequently confirmed by Dr. Henderson and others. Supposing, then, that 5 cubic inches of azote are consumed every minute by a moderately sized man, 22.464 grains will be expended in twenty-four hours.

Allen, Pepys, and Jurine, on the other hand, have endeavoured to prove, that azote is given out by the lungs during respiration, and their proof has been collected from many ingenious experiments; while Ellis has laboured to show, that respiration leaves the natural azote of the atmosphere untouched in quantity and unchanged in quality. The experiments of Spallanzani render it certain that reptiles absorb azote, and Humboldt and Provençal have ascertained that the same effect is produced upon inspired air by fishes. Admitting, however, that Davy's experiments are to be depended on, the quantity of azote consumed by respiration, when compared with its absolute amount, is so trifling, that one should think this gas must operate upon the well-being of life, in a way and to an extent that are not as yet understood. Out of 100 parts of common air, 77 consist of azote, 22 of oxygen, and 1 of carbonic acid; so that, supposing the alleged diminution of this gas to occur, the loss which it sustains within the lungs bears little proportion to its original quantity.

Oxygen, the second ingredient of the atmosphere, composes little more than one-fifth of the whole mass; yet, when frequently respired, it can be made entirely to disappear. If air be examined which the smallest insect has respired, the oxygen contained in it will be found diminished or consumed; if fishes be immersed in water which has been deprived of this gas by boiling, they languish and die It matters not what element is inhabited, or what functions are performed; whether the animal breathe by lungs or gills; whether the air traverse every part of the body, or be confined to a single organ, oxygen is equally indispensable. It is this gas which renders the atmosphere essential to life; yet, when undiluted with azote, it cannot support continued respiration. When pure oxygen is inspired, a sense of warmth is felt in the chest, the heat of the skin is raised, the pulse is quickened, and other symptoms of excitement are produced. Lavoisier inspected the bodies of animals which had been for some time immersed in this gas; increased redness, unusual vascularity, and other indications of inordinate action, were discovered. Dumas states, that the lungs of a dog, which had been exposed to a similar trial, were even ulcerated. Pure oxygen appears, therefore, to be unfit for the maintenance of life; its dilution is requisite, and azote seems to be the appropriate diluent. We know that, in a separate state, azote is innoxious. Alone, it cannot be inspired; but it appears to be irrespirable only because destitute of oxygen, and

the proportions in which nature has compounded these aërial liquids, as they are met with in the atmosphere, are exactly those which render them most suitable for the economy of life. If the oxygen be diminished, the compound produces a sense of languor, and a tendency to sleep; if it be increased, the effect is stimulating. Mr. Ellis has stated, that the growth of vegetables is much injured when they are surrounded with too much oxygen; and it is equally certain that insects, if immersed in this gas in an unmixed state, die long before it is consumed. Saussure mentions a strong tendency to sleep as one of the sensations he experienced while traversing the summit of the Alps; but the accounts which some travellers give of the effects of elevated regions upon their respiratory organs may perhaps be more plausibly attributed to the increased rarity of the air, than to the diminished quantity of its oxygen. A small quantity of pure oxygen, indeed, will often support life longer than the same quantity of atmospheric air; but from its well-known tendency to excite, it may be inferred that its continued use would be injurious, if not fatal. Blumenbach procured three dogs of the same size: into the trachea of the first he inserted a pipe, which had attached to it a bladder, containing 20 cubic inches of oxygen;—after fourteen minutes the animal died. The bladder was then filled with atmospheric air, and its pipe was fixed into the windpipe of the second dog; in six minutes it expired. The air, which had been thus respired for six minutes, was made the subject of the next experiment on the third dog, which died four minutes after the introduction of the pipe.

The precise quantity of oxygen, which is necessary to support human life, it is not easy to calculate. Menzies states, that in twenty-four hours 51.840 cubic inches, or 17625.6 grains, are consumed by an ordinary man; Lavoisier raises the quantity destroyed in the same period to 46037.38 cubic inches, or 15661.66 grains; and the experiments of Davy lead to the conclusion, that 31.6 cubic inches are consumed every minute, making the quantity necessary for twenty-four hours 45.504 inches, or 15471.36 grains. From the trifling discrepancy between the last two results, it is probable that the quantity of oxygen, necessary for the maintenance of human life during twenty-four hours, may range between 45 and 46.000 cubic inches, which, when weighed, make about 15.500 grains, or 2 lbs. 8 oz. troy. The variety, however, to which the consumption of this gas is exposed is very great. Scarcely during two hours in the day does the same person employ the same quantity. The nature and degree of his exercise, his condition of mind, his state of health, the kind of food he eats, the temperature of the air he breathes, and many other modifying causes, materially influence its consumption. When the hourly waste of oxygen, at the temperature of 54°, amounted to 1345 cubic inches; at 79°, it was found to fall to 1210: during digestion, more disappeared than when the stomach was empty, and less was required, as the quantity of vegetable food that had been taken was great. When the mind is tranquil and the body is at rest, comparatively little is necessary; active exercise and mental agitation require a more liberal supply. But where does all this oxygen go? For what purposes is it abstracted? To answer these questions we must inquire into the change which respiration effects upon the third gaseous constituent of the atmosphere—carbonic acid.

Unlike azote and oxygen, which are simple gases, *carbonic acid* is a compound of two substances, oxygen and carbon; and so incapable is it of supporting flame or life, that a taper is extinguished by being immersed in it, and it cannot, for even a moment, be inspired without causing a feeling of suffocation. Many experiments were performed upon this gas by the courageous Pilatre de Rozier. In one of these, he entered a brewer's tub during the fermentation of its contents, when carbonic acid was exhaled in clouds. A sensation of heat and itching was first experienced; this was speedily followed by difficult breathing, and a violent sense of suffocation; he could no longer distinguish objects; his face became purple, his limbs weak; he understood with difficulty what was said to him; and it was not until he had been again exposed for some time to pure air that these formidable symptoms were removed. Davy tried to inspire a mixture of two quarts of common air with three of this acid, without success; but, by increasing the proportion of common air to seven quarts, the mixture became respirable. When used in an undiluted

state, a burning sensation at the top of the uvula, and a violent feeling of suffocation, were complained of: giddiness and torpor were its effects when mixed with common air. It is not to be expected, therefore, that a gas of such deleterious properties should enter largely into the composition of a fluid so essential to life as atmospheric air; accordingly, it scarcely exceeds one per cent., and it is probable, that even this quantity owes its presence more to chemical decomposition than original arrangement.

Let it be supposed that 100 parts of common air be respired by different animals, whose pulmonary habitudes are different, until they be no longer respirable even by an insect. It will be found that, in place of being composed of 77 azote, 22 oxygen, and 1 carbonic acid, they consist of 77 azote, and 23 carbonic acid. For the sake of round numbers, this statement is made general; but this point, like almost every other on the chemistry of respiration, is far from being settled; some maintaining that the oxygen lost is exactly replaced by the carbonic acid gained, while others assert that the carbonic acid added is less than the oxygen consumed. In ordinary respiration, however, air, which has only once visited the lungs, has not parted with all its oxygen. According to Dr. Goodwyn, a quantity of air taken into the lungs at a single inspiration, containing 80 parts of azote, 18 oxygen, and 2 carbonic acid, had its composition altered, after the experiment, into 80 azote, 5 oxygen, and 13 carbonic acid; 2 parts of the whole having entirely disappeared, and 11 parts of carbonic acid having been substituted for 13 parts of oxygen. Both classes of physiologists maintain that, whatever be the quantity of oxygen abstracted, the quantity of carbonic acid formed is nearly, if not altogether, an equivalent; and that this is the case whether the respired air be once or one hundred times inhaled. According to Menzies, $\frac{1}{20}$th part of air which has been once respired, is carbonic acid, and his estimate of the quantity formed during 24 hours is 24105.6 grains troy; according to Lavoisier, it amounts to 17720.89; to Davy, to 17811.38 grains troy. From the great discordance which exists between the estimates of Lavoisier and Davy, when compared with that of Menzies, there is reason to believe that the computation of the last has been considerably overrated; yet, admitting it to be excessive, those of the former are insufficient to account for all the oxygen consumed. Lavoisier supposed that 15661.66 grains of oxygen were expended in 24 hours; but 12924 are sufficient to form the 17720.89 grains of carbonic acid generated during the same period—leaving a residue of 2737.66 grains of oxygen unaccounted for. Again, Davy calculated that 15337 grains of oxygen were necessary for twenty-four hours' expenditure; but 12824.18 only are required for the formation of 17811.38 grains of carbonic acid during the same period, giving us an unexplained overplus of 2512.2 grains of oxygen. Now, as no subsequent experiments of any note can throw these conclusions into discredit, it may be concluded that the whole of the oxygen which respiration abstracts from the air is not accounted for by the carbonic acid which it generates—that some disappears without leaving behind any equivalent. What becomes of this residual oxygen it is difficult to say. Some believe that part of the watery vapour which is exhaled during expiration is occasioned by the union of a portion of the oxygen of the air with hydrogen extricated by the lungs from the blood; others assert that it is absorbed into the blood, and is lost in its course around the system; and it has likewise been said that the alleged deficiency depends upon the condensation which oxygen experiences by being converted into carbonic acid, and is, therefore, more apparent than real. That part of the vapour which is expired from the lungs may be the result of this union of oxygen with hydrogen, is probable; but when it is considered that upwards of 20 ounces of water are exhaled every twenty-four hours from the lungs of an ordinary man, it would seem reasonable to ascribe some of it to evaporation of the mucous secretion of the bronchi. The absorption of oxygen into the blood is a subject which will be hereafter entered on; and the supposed condensation of this gas, when it unites with carbon, stands unsupported by adequate proofs. It must be borne in mind, that the same causes which affect the consumption of oxygen have an equal influence upon the formation of carbonic acid, and that, therefore, every calculation which is made in the present state of this inquiry must be regarded only as an approximation to the truth. The investigations of Prout show that carbonic acid is exhaled in different quantities during different pe-

riods of the day ; and Fyfe has ascertained that its evaporation is much decreased by the use of wine, that it is reduced to almost one-half by vegetable food, and nearly to one-third by a course of mercury. According to Prout, it is generated in the greatest quantity about noon ; from one until eight in the afternoon its exhalation gradually decreases, when it remains at its minimum until three in the morning, after which it increases until twelve, when its maximum is attained ; so that general conclusions upon a point like this, when the experiments upon which they are founded may be disturbed by so many circumstances, cannot be much depended on.

Effects of Respiration on the Bulk of inspired Air.

There can be little doubt that the air which has been employed in respiration suffers some diminution in volume. Goodwyn supposed it to be reduced $\frac{1}{60}$th in bulk. Abernethy, on the contrary, asserts that its volume, instead of being diminished, is increased. Sir H. Davy found that air which had passed through the lungs once only, suffered a diminution of from $\frac{1}{160}$th to $\frac{1}{50}$th, but that when it had been repeatedly respired, it lost $\frac{1}{18}$th of its original bulk ; while Thomson is inclined to ascribe any trifling variation which may occur to accident during the experiment, or to its absorption by the lungs, independently of respiration.

An ordinary man, in a state of health, is found to take into his lungs, at an ordinary inspiration, about 40 cubic inches of air, all of which we may suppose he afterwards expels by an ordinary expiration. Menzies has proved, that after an ordinary expiration the lungs can be made to expel, by an increased effort, 70 cubic inches more ; and Goodwyn has calculated that 109 cubic inches still continue in these organs, after they have performed the very fullest expiration. So that the quantity of air contained within the chest after an ordinary expiration is $109+70$ cubic inches $=179$ cubic inches, and, after an ordinary inspiration, $109+70+40=219$ cubic inches. But nothing can be more variable than such calculations. One man requires more air than another, and the same man will consume, under dissimilar circumstances, different quantities. As long as there are different pulmonary conditions in health and sickness, during ease and exercise, in lungs differently proportioned, and in constitutions differently formed, the abstract fact, that one effect of respiration is to diminish the bulk of the air respired, may be considered certain ; but the precise amount of this decrease must remain undetermined.

Effects of Respiration on the Properties of the Blood.

Having seen that the oxygen of the atmosphere is essential to life ; that all airs are respirable only in proportion as it enters into their constitution ; that a great quantity of it disappears during respiration ; that it is replaced by an almost equal volume of carbonic acid ; and that the azote, with which in atmospheric air it is so largely intermixed, is more serviceable as a vehicle for its introduction to the lungs than for any intrinsic properties of its own ;—a question naturally arises, how is this oxygen converted into carbonic acid, and what effect has such conversion upon the properties of the blood ? We have seen that there are two different kinds of blood—venous and arterial ;—that venous is darker than arterial blood ; that the latter, during its circulation round the body, contracts noxious properties, upon which the dark colour of the former depends, and by which it becomes disqualified for the purposes of life ; that these noxious properties, and this dark colour, are abstracted from venous blood during its passage through the lungs ; and that one great object of respiration is to furnish the arteries with pure, nutritious fluid, by converting that which was contained in the veins into arterial blood. Now, although the precise mode in which this change is accomplished be still obscure, there is no question that the change does take place, and the general principles by which it is effected are ascertained.

It had been often remarked, that the blood of the right auricle was much darker than that of the left, and that the vermilion red of the latter seemed to be obtained during the passage of the blood through the lungs. It had been likewise noticed, as a singular occurrence, that the surface of blood which had been exposed to the air either became or continued red, while its under-surface remained black. This phenomenon was, however, explained away upon the principle of different specific gravities,—the black or weightier portion falling to the bottom, while the red or lighter portion

floated at the top; and it was not until the middle of the seventeenth century that the real action of the air upon the blood began to be perceived. By removing the surface of blood which had been for some time exposed to the air in an open vessel, Lower discovered that the new surface was soon converted into as bright a red as that possessed which he had previously removed; and to refute the opinion, that the different gravities of different portions of the blood furnished an explanation of this phenomenon, he inverted cakes of coagulated blood, exposing their black under-surfaces to the air,—when they also speedily assumed a florid hue. The conclusions countenanced by these observations were rendered still more unquestionable by subsequent experiments. Hewson injected air into the veins of a rabbit, by which its venous was changed into arterial blood; and Cigna, by placing blood within the vacuum of an air-pump, showed that the reason why its colour remained unchanged was its exclusion from the atmosphere.

Nevertheless, there was one circumstance which appeared, even to those who were otherwise satisfied with this explanation, exceedingly unaccountable. Even admitting that the florid colour of arterial blood depends upon the chemical action of inspired air, how can this air gain access to venous blood circulating within the substance of the lungs, seeing that the membranous sides of the air tubes as well as the membranous coats of the blood-vessels intervene? An experiment performed by Priestley completely removed this difficulty. "I took," says this philosopher, "a large quantity of black blood, and put it into a bladder moistened with a little serum, and, tying it very close, hung it in a free exposure to the air, though in a quiescent state, and the next day I found, upon examination, that all the lower surface of the blood which had been separated from the common air by the intervention of the bladder, and likewise a little serum, had acquired a coating of a florid red colour, and as thick, I believe, as it would have acquired if it had been immediately exposed to the open air; so that the membrane has been no impediment to the action of the air upon the blood." This experiment was repeated without previously moistening the bladder, and with the same result. Now, as it was found by Hales that the membrane, of which the air-cells are composed, is only $\frac{1}{1000}$th part of an inch in thickness, these experiments of Priestley were held decisive of the point, that the intervening membranes, which separate the air from the blood in the air-cells of the lungs, could not prevent these fluids from acting on each other. But two questions of interest still remained: how did the air, by coming into contact with venous blood, render it arterial?—and how did blood, once rendered arterial by such contact, again become venous? Before the time of Priestley, conjectures the most vague were entertained respecting the air's action upon the blood. One believed that it communicated to it a saline vapour; another, a volatile salt; while some maintained that the blood received nothing from the air, but that the air got something from the blood. But after this sagacious philosopher had revealed the composition of the atmosphere, and a better knowledge of the laws of life had displaced the crude doctrines of mere chemical and mathematical physiology, the real purposes of respiration became apparent, and the agency of the air upon the blood intelligible. Goodwyn enclosed a quantity of oxygen gas in a glass receiver, which he inverted over quicksilver, and then introduced into it four ounces of blood, which had been just drawn from the jugular vein of a sheep, when it instantly became florid. Atmospheric air was then substituted for oxygen, the colour of the blood was less speedily effected; and when carbonic acid was employed, its colour was changed to a dark purple. These experiments led to results of such interest, that their accuracy was at first questioned; but being carefully repeated and frequently varied, it came at length to be established as a fact, which at present all admit, that the constituent of atmospheric air which converts venous into arterial blood, is oxygen.

Theory of the Reciprocal Action of the Air and Blood.

By mixing arterial blood with carbonic acid, it is found to assume a venous hue; by mixing venous blood with oxygen gas, the arterial aspect is restored. The inference has just been stated, that the principle which renders arterial blood venous is carbonic acid, and that oxygen is the agent by which venous is converted into arterial blood. As

carbonic acid is composed of oxygen and carbon, and as it is certain that oxygen is the arterializing principle, it is obvious that carbon is the only part of this acid which can deteriorate the blood. It has been shown that the oxygen of inspired air is converted into carbonic acid during its stay in the air-cells; that the removal of carbon from venous blood renders it arterial; and that carbonic acid is composed of oxygen and carbon. It is a reasonable inference, that the carbonic acid expired from the lungs results from a union of the carbon of venous blood with the oxygen of inspired air. How or where this union is accomplished it is somewhat difficult to determine. Some suppose that the oxygen of the air attracts the carbon of the blood from the minute branches of the pulmonary artery, and that these elements unite in the air-cells; by others, it is maintained that the carbon of the blood attracts the oxygen from the air-cells, and that they unite in the blood vessels. In the one case, it is conjectured that carbon is exhaled from the blood into the air cells, where it meets with the oxygen of the inspired air, and is there converted into carbonic acid; in the other, it is argued that oxygen is inhaled from the air cells into the blood, where it meets with the carbon of venous blood, and is there converted into carbonic acid, which is thrown out into the air cells during the blood's passage through the lungs. Both doctrines have been espoused by men of equal talents, and many striking arguments have been adduced in support of each. The former boasts the names of Priestley, Lavoisier, and Crawford; the latter is maintained by La Grange, Davy, and Edwards. "It is well known," says Crawford, "that the blood undergoes a remarkable change of colour when circulating in a living animal; for the vivid arterial blood, in its passage through the capillaries to the venous system, acquires a deep and livid hue, and again resumes its light and florid colour in the lungs. Dr. Priestley has proved that similar alterations are produced in the colour of the blood by exposure to pure and inflammable (carbonic acid gas) air. Since, therefore, the arterial blood undergoes the same change of colour in the capillaries that it suffers by exposure to inflammable air; since it has an attraction to that fluid; and since the separation of inflammable air from animal substances is promoted by heat and by the tendency of the juices to putrefaction, we may, I think, safely conclude that the change which the blood undergoes in the capillaries arises from its impregnation with this principle. And as the absorption of inflammable air, or its basis (carbon), is the cause of the change which is produced in the colour of the blood during its circulation through the capillaries, we may also conclude that when the blood again recovers its florid colour in the lungs, the inflammable principle is detached."

Although the general groundwork of this theory is considered sound, it assumes some points which are either false or insufficiently supported. It supposes that the blood does not receive its carbonizing principle until it reach the extreme capillaries of the aortic system. But Mr. Hunter has proved the contrary. Having exposed the carotid artery of a dog and passed two ligatures around it, at the distance of two inches from each other, he punctured the included vessel after the expiration of some hours, when dark-purple blood issued from the puncture; proving that arterial blood may be rendered venous without passing into either a capillary vessel or a vein. The same fact was shown by Hassenfratz. A number of glass tubes were filled with arterial blood, and hermetically sealed; the blood gradually began to change colour, and after some time became perfectly purple. It likewise supposes that the carbon of venous blood is attracted from the vessel which contains it by the oxygen of the air-cells; but many facts and appearances could be advanced decidedly favourable to another view. M. Vogel placed a quantity of venous blood within the receiver of an air-pump, and, having exhausted the receiver, a quantity of gas was seen to escape from the blood, which proved upon examination to be carbonic acid. But, as the existence of carbonic acid in the blood supposes the presence of oxygen, and as the lungs are the most likely organs through which this gas could gain entrance into the circulation, this experiment, which has been verified by Sir E. Home, must appear decisive as to the introduction of oxygen into the blood. The following experiment of Edwards is in support of the same view. He confined some frogs in hydrogen gas, and, by using certain precautions, succeeded in making them respire it for some time. When the hydrogen was examined after the

experiment, a quantity of carbonic acid, of nearly equal volume with that of the animals themselves, was found mixed with it. Some of the oxygen which formed this acid may have been within the air-cells of the frogs' lungs before the experiment; but the quantity of acid found after the experiment is incompatible with the supposition, that all the oxygen required for the formation of this acid could be derived from this source.

In the present treatise, however, it is impossible to enter into the merits of this controversy with a minuteness proportioned to its interest. We can only observe, that the theory of La Grange, which maintains that the venous blood, when it arrives at the lungs, absorbs a quantity of the oxygen contained within the air-cells; that this oxygen, during its circulation, combines with the accumulating carbon of the venous current, and forms carbonic acid; that this carbon may enter the circulation at any period of its progress; that by the time it arrives at the right side of the heart it has so increased, that the welfare of the system renders its expulsion necessary; and that with this view it is thrown out into the air-cells of the lungs in the form of carbonic acid;—is more consonant with common observation, more consistent in point of principle, explains the greatest number of difficulties, and is supported by the strongest facts. It explains how arterial blood may be rendered venous without leaving the arteries; how venous blood becomes darker as it approaches the lungs; how that oxygen is disposed of for which the carbonic acid does not account; how carbonic acid can be extricated from blood under the receiver of an air-pump, or exhaled by animals while respiring a gas which is destitute of oxygen; and how caloric is so evolved during the circulation of the blood, as to maintain every part of the body in a uniform degree of temperature.

Considering that the great object of respiration is to enable the carbon of venous blood to enter into chemical combination with the oxygen of the atmosphere, it must be admitted to be of little consequence whether the carbon unite with the oxygen in the air-cells, or in the blood-vessels. To bring about their union is the important point, and that they do unite is certain, from the disappearanceof both—of carbon from venous blood, and of oxygen from inspired air; that they do form by this union carbonic acid is also certain, from the fact, that this acid is generated in proportion as they disappear; and that the superior properties of arterial over venous blood must result from this union is established from the necessity of arterial blood for the purposes of life, and the necessity of oxygen for the formation of arterial blood. What part of the blood this oxygen acts upon, whether on the colouring matter, fibrin, albumen, or serum, is a question of curious interest, but of too abstruse a nature for discussion in the present place; and how tne blood, during its circuit round the body, is so constantly and so largely supplied with carbon, is a subject of inquiry, which will come more aptly before us when we treat of the functions of the absorbent system.

Theory of Animal Heat.

While considering the phenomena of life, it was observed that one of the most characteristic attributes of a living being is its faculty of resisting extremes of temperature. The porpoise, which lies buried beneath mountains of polar ice, is as warm as any of its own species which may be swimming beneath the Line; the Ethiopian, who scorches beneath a vertical sun, and the Laplander who is cradled in the snowy bosom of the North, enjoy the same degree of animal heat; man, wherever born, can go through the wide range of external temperature which lies between the freezing and the boiling points, without undergoing the slightest alteration in that of his own body. But a tendency to an equilibrium is a law to which caloric is uniformly obedient: there must be, therefore, a constant evolution of this substance from the surface of the human body, and a constant effort on the part of the surrounding atmosphere to reduce its temperature to a level with its own. Did this law operate on man without some countervailing influence, and were he, at the same time, subjected to the vicissitudes of temperature to which he is now obnoxious, his circulation would be interrupted or arrested; at one time his fluids would be congealed, at another evaporated, and the current of life would flow unequally, or would wholly cease. To avoid such consequences, a certain temperature is preserved, with an almost perfect uniformity, and in all animals it is somewhat above that of the medium in which

they live. The arrangement by which this uniformity of temperature is maintained is so perfect in itself, and so steady in its operation, that no ordinary degree of external heat or cold can materially affect it. It is true that a degree more or less may occasionally result from a sudden exposure to great vicissitudes; but such an elevation or depression, even when it does occur, is as trifling as it is transient.

This phenomenon was formerly resolved into an ultimate law in the animal economy; but it is now proper to endeavour to shew how animal heat is elaborated in the system, and by what physical means its uniformity is preserved. As soon as the general nature of respiration was understood, and its various conditions in different animals were discovered, two circumstances were observed to be invariable in their occurrence, and inseparable in their concurrence. It was found that all those animals which breathe have a temperature higher than that of the medium in which they live, and that this excess is strikingly proportional to the quantity of air respired. The temperature of the slug-worm, which breathes within the bowels of the earth, and the respiratory function of which must be necessarily so imperfect, is two or three degrees only above that of the clay which surrounds it; on the other hand, the heat of birds, which, of all animals, consume most air, is of all animals the greatest. When the temperature of the atmosphere was 56°, Mr. Hunter found that of the earth-worm to be 58°5′; while the thermometer rose to 140° when inserted into the body of the common fowl. Asthmatic patients, whose lungs either take in an insufficient quantity of air, or inefficiently act upon the air received, are, in general, some degrees cooler than such as have a healthy pulmonary system; birds, while in a state of torpor during winter, are nearly as cold as they are inert; and, in a word, so universal is this connexion between the generation of animal heat and the consumption of air, that the degree of perfection in which the respiratory apparatus exists in different animals is a certain index of their temperature, and their temperature of their respiratory function.

Striking as these facts appear, and obvious as the inference now seems to which they point, it was long before that inference was drawn. Corpuscular attraction, vascular friction, fermentation, and combustion, long occupied and obscured the minds of physiologists; and even when these vague conjectures had sunk into merited contempt—when, at length, it was clearly seen and generally acknowledged that there was a close and inseparable connexion between animal heat and respiration, still, the nature of that connexion remained wholly unknown. Assuming this relationship as established, Crawford had the great merit of founding upon it a theory, which for simplicity and beauty is scarcely to be exceeded by any that adorn the history of science. It is a general law, to which there appears to be no exception, that oxygen cannot combine with carbon without evolving heat: it is proved by experiment that venous blood has a less capacity for heat than arterial blood: when venous blood becomes arterial, its sensible heat remains unaffected, but its specific heat is increased, and therefore a constant supply of fresh caloric is required to maintain venous blood, of a given temperature, at the same temperature when it is converted into arterial. Now, it is maintained by Crawford, that this supply of fresh caloric is afforded in the lungs by the union of the oxygen of the air with the carbon of the blood; that the caloric generated by this chemical combination is entirely consumed in satisfying the increased capacity of arterial blood for heat; that, consequently, the temperature of the lungs is no greater than that of the heart, or of any other organ; that as the blood, arterialized in the lungs, in circulating through the body gradually becomes venous, its capacity for caloric diminishes; that as its capacity for caloric diminishes, heat is evolved; and that in this manner every part of the system is constantly maintained in an equal degree of temperature.

To the establishment of this ingenious theory, it is necessary only to prove two things: first, that oxygen cannot unite with carbon, to produce carbonic acid, without the evolution of heat; and secondly, that the capacity of arterial blood for heat is greater than that of venous blood. The establishment of the first point is essential, because it is necessary to explain the source of animal heat; while the proof of the second is equally indispensable to account for its uniform distribution.

The first point is universally admitted: for whether it be during combustion, fermentation, putrefaction, ger-

mination, or any other process in which carbonic acid is produced, heat is invariably given out, and the amount of carbonic acid formed is a tolerably accurate measure of this increase of temperature. But it has been proved that the lungs are manufactories of carbonic acid, and that the quantity of oxygen abstracted from respired air is replaced by very nearly the same quantity of this acid; therefore, when it is inferred that respiration, like combustion or fermentation, is a calorific process, the inference is not only supported by strong analogies, but grounded upon a steady and settled principle.

The second point is, perhaps, less certainly established. It is true that arterial blood is generally allowed to be one or two degrees warmer than venous blood; but when the great quantity of caloric, which the formation of so much carbonic acid within the lungs must evolve, is considered, this trifling elevation of temperature in arterial blood can be scarcely deemed sufficient to account for it. Some have considered this circumstance sufficient to overturn Crawford's theory, and certain experiments upon decapitated animals have encouraged others to maintain that animal heat is a secretion depending upon the brain and nerves. But the admitted facts that oxygen has a greater capacity for heat than carbonic acid; that carbonic acid is never generated without being accompanied by the evolution of caloric; that carbonic acid is found in profuse quantity during respiration, while an equal or greater quantity of oxygen is consumed; that young animals generate the least heat, while they use the least oxygen; that the temperature of hybernating animals is but a slight degree above the medium in which they live; that the temperature of all animals, whether hot or cold-blooded, is directly proportional to the quantity of oxygen inspired; and finally, that those very periods in the day, during which oxygen is inspired in greatest quantity, are the very periods when animal temperature attains its highest point;—all such facts (and they could be much extended) must be held strongly favourable to the inferences, that the union of the oxygen of the air with the carbon of the blood is necessarily productive of heat; that this union occurs during respiration; that the caloric formed by respiration is either almost or altogether expended in satisfying the increased capacity of arterial blood for heat; that this latent heat of arterial blood is rendered sensible during the circulation by the gradual conversion of arterial into venous blood, and that when the blood has become as highly venalized as possible, and all its latent heat has become evolved, it receives a fresh quantity in the lungs during the combination of its carbon with the oxygen of inspired air*.

Subordinate Effects of Respiration.

The purification of the blood and the generation of caloric are certainly the first and the most important effects of respiration; but beyond these there are many other objects which it serves. It is by it that we are capable of voice and speech; it is through it we derive the most valuable part of social intercourse; it is to it we owe the inestimable advantages that result from the communication of thought, and the exquisite pleasures that flow from harmonious vocal sounds, and from the still sweeter accents of affection.

It has been observed by Aristotle, that such animals only as possess lungs have a true voice; and this opinion the experience of modern naturalists confirms. It is true that many insects, and some other tribes of inferior beings, can emit certain sounds; but these sounds depend upon vibrations of the air, produced by the agitation of their external organs, and not upon any specific vocal mechanism.

Attempts have been made to ascertain how many varieties of tone the human voice is capable of emitting. Haller could articulate during one minute no fewer than 1500 letters; and as the articulation of each letter required the action of many muscles, several thousand distinct contractions and relaxations must have been performed in that period. Dr. Barclay observes, that, as the muscles of the larynx are at least seven pairs, fourteen muscles, which can act separately or in unison, are capable of producing 16,383 different movements, without bringing into the calculation the different degrees of force, or the infinitely varied order of succession

* While this theory of the generation of animal heat must be admitted to be highly ingenious and beautiful, experiments have been performed by Dr. Wilson Philip and others, from which it has been inferred that animal heat is a product of secretion; and that, like other secretions, it is very much under the influence of the nervous system. In this place we can only refer the reader to Dr. Philip's excellent treatise on the Vital Functions, both for the facts and the inferences.

in which they may be occasionally made to act. But in addition to these proper vocal muscles he enumerates fifteen other pairs, which are either employed in preserving the articulation of the larynx steady, or in regulating their general movements, as occasion may require. These fifteen pairs of muscles, when acting alone, are susceptible of 1,073,741,823 different combinations, and when co-operating with the succeeding seven pairs, give the following number, 17,592,186,044,415, as a gross estimate of the different varieties of movement which the different parts composing the human larynx are capable of producing. But each of these movements will elicit a distinct tone of voice; and when it is considered that each movement may be variously modified in intensity, and not only so, but that these several modifications of movement may be indefinitely combined, it is obvious that no limit can be ascribed to the range of the human voice, and that the varieties of its tones cannot be numbered.

Fœtal Substitute for Respiration.

If the lungs be organs of such vital influence that respiration is indispensable to life, that animals of the simplest construction require air, and that corporeal vigour and mental energy are intimately connected with the due arterialization of the blood, it may appear singular that the young of all animals, whether oviparous or viviparous, do not respire before birth, and that their blood experiences no alteration in their lungs. While the chick is enclosed within the egg, it possesses a sanguiferous system as minute as after incubation has been completed; its arteries carry red and its veins purple blood: and the fœtus, while in its mother's womb, is freely and faithfully supplied with this vital fluid in a purified state. During fœtal life, secretion and absorption are regularly performed, nutritive matter is deposited, excrementitious particles are removed, and the blood experiences the same kind and amount of alteration during its journey round the system it supplies, as is witnessed after birth. How, then, is the noxious carbon, which is ever adulterating the vital current, abstracted from the blood? — where is oxygen procured to convert it into carbonic acid?—and if carbonic acid be formed, how is it expelled? In the incubated egg, this seems to be accomplished in the following way: the shell is exceedingly porous, and is internally in close contact with a very vascular membrane, which forms the external envelope of the contents of the egg. This membrane circulates more blood than is devoted to the body of the chick, and is separated at the greater end of the egg into two layers, which form a circular space, or bag, that is filled with air. This bag, or air-cell, is at first not more than a quarter of an inch in diameter, but as incubation proceeds it progressively enlarges, and towards the close of the process occupies a very considerable portion of the general cavity. Now, Spallanzani has ascertained that eggs freely absorb oxygen from the atmosphere, that the degree of this absorption is directly as the quantity of animal matter they contain, and that the air enclosed within these air-cells betrays a deficiency of oxygen and an excess of carbonic acid. It is, therefore, believed that the conversion of venous into arterial blood during incubation is accomplished by bringing the blood, as it deteriorates, to this vascular membrane which lines the shell, where it is purified by the air which enters through the pores with which the shell is permeated. This vascular membrane is equivalent to the minute ramifications of the pulmonary artery in man, and the porous shell is a counterpart to the walls of the air-cells of the human lungs. The former furnishes a sufficient surface whereon the venous blood may be spread, and the latter a convenient medium through which the oxygen of the external air may exert its peculiar influence upon this fluid. Air is as essential to the progress of an incubated egg, as to the existence of the chick after the shell is broken; and nothing more is necessary to arrest this process by suffocating the chick, than to exclude the external air by closing the pores of the shell with oil.

In the young of aquatic animals, various contrivances are employed to oxydate the blood in consistency with the medium they inhabit; and in the human fœtus, a vascular organ called *placenta*, which in office is similar to the lining membrane of the egg, is considered the fœtal substitute for respiration. This organ is principally composed of two distinct sets of blood-vessels, separated from each other by intervening cells. One set of these vessels is attached to the womb of the mother, and belongs to the mother's system; the other unites

to form the umbilical cord, and belongs to the system of the child. The vessels, therefore, which supply the child, and those which connect these vessels with the mother, are perfectly distinct. Injection poured into the one set will not pass into the other, and the communication which they enjoy is maintained only through the interposition of cellular cavities. Now, it is within these cellular cavities that the work of oxydation is supposed to go on; but, whether these cells possess the prerogative of absorbing carbon from the fœtal vessels which lie on one side of them, and oxygen from the maternal vessels which ramify on the other, or whether of themselves they exert some change upon venous blood equivalent to oxydation, is at present unknown. Argument may be used in support of either view; but the investigation is so incomplete, that it would be vain to attempt to anticipate a result, which careful experiment and diligent research can alone obtain. One circumstance only is known with certainty, that the blood which the child sends to these cells is venous, that the blood which it receives from them is arterial, and that the alterations which the lungs are destined to work upon this fluid after birth are effected, during fœtal life, by, or at least through the placenta.

Having now concluded our description of the three great functions of life—digestion, circulation, and respiration; having shown how the food is converted into blood, how the blood is circulated through the body, how the noxious qualities with which it becomes tainted during its journey are removed, and its purity maintained, it will be necessary to consider the ultimate design of such an elaborate system, to investigate the reason why blood must be so freely supplied by the stomach, so constantly circulated by the heart, and so regularly purified by the lungs. And this brings us to the subject of secretion.

Secretion.

At no period of life is the human body perfectly complete. At birth the process of development is still unfinished; during infancy every organ is weak, and every function is imperfect; at the period of puberty, parts previously unexercised suddenly enlarge, and take on new actions: manhood, requiring in the discharge of its offices the utmost extent of power, brings every resource of the system into full operation; while, in old age, functions no longer necessary are gradually withdrawn, and organs which have ceased to discharge duties no more required insensibly decay.

The machinery by which this reparative system is conducted is extensive and complex. Nutritive matter taken into the stomach is there converted, as we have seen, into chyle; chyle is converted by the lungs into blood; blood is carried to every part of the system, and in every part of the system is changed into those substances which are necessary either for its growth or reparation. Wherever muscle is required, muscular fibre is deposited; where bone is needed, ossific particles are laid down in the requisite form and in the desired order; where it is necessary to construct cellular tissue, or to deposit fat, albuminous and oily matter are provided. The process by which these different substances are eliminated from the blood is termed *secretion;* that by which they are removed when no longer useful is called *absorption:* the result of both actions combined is denominated *nutrition.* The first process is preparatory to the second, and both are essential to the third. Were the old particles not regularly removed, new particles could not be regularly deposited; and were not fresh nutritive matter ready for deposition as absorption proceeds, emaciation would be the first, and death the ultimate and the speedy result.

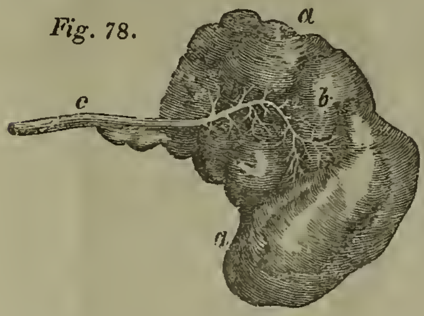
How the chyme is elaborated in the stomach by the gastric juice, how the chyme is converted into chyle in the duodenum, how the chyle is arterialized in the lungs by the action of the air, and how the arterialized blood is transmitted by the blood-vessels to every organ in the body, have been already shown; but it still remains to be explained how this common fluid, which exhibits the same properties in every part of the circulation, can be converted into bone and brain, into muscle and membrane, into cartilage and fat; how saliva and bile, how urine and mucus—fluids the most active and the most insipid—can be manufactured in determinate quantities, in certain textures, and at appropriate periods, out of a bland material totally unlike any and every substance which it generates!

Organs of Secretion.

The apparatus by which the animal se-

cretions are formed assumes a thousand modifications of external aspect. Sometimes nothing can be discerned but a smooth vascular membrane, such as the pleura which lines the chest, or the pe-

Fig. 78.



A gland with an excretory duct. *a a* the substance of the gland irregular and lobulated; *b b* the small branches by which the excretory duct rises from the gland; *c* the trunk of the excretory duct fully formed.

ritoneum which envelops the viscera of the abdomen. At another time this membrane is not smooth, but rough, and covered with small vascular elevations. called *villi*, giving to this entire surface a velvety appearance. In one organ the secreting membrane assumes the form of small bags, called *follicles*, which contain an aperture in their centre for the transmission of the substance secreted by their internal surface. In another it constitutes sacs, open at one end, denominated *lacunæ*, which are sometimes single, as in the nose—sometimes ramified, as in the neck of the womb. Again, the wax which defends the passage to the internal ear seems to be secreted by small membranous cavities, which open, by means of small ducts, upon the surface of the auditory canal; while the oily matter which is formed beneath the cuticle, more especially in the armpits and groins, appears to be a secretion produced by bodies similarly constructed, and of the same figure. These small secreting bags are known by the name of *glands*, and the small tubes through which they convey the secretions they elaborate are styled *excretory ducts*. But different as the external characters of all these secreting organs may be, yet their general structure is essentially the same; and the more carefully the secreting apparatus is examined, the more convincing will appear the reason for believing that every external modification of structure has been adopted for the sake of convenience rather than because it was indispensable: nothing appears absolutely necessary to the performance of secretion, save capillary blood-vessel. The chain of connexion between the simplest secreting surface and the most complex gland, of which only the first links have been now given, might be easily completed, by tracing the gradual complication of an elementary secreting organ, as it appears in a serous membrane, up to the most elaborate specimen of glandular structure.

When a bone is broken, blood is poured out into the fracture, and there coagulates. After a short period, vessels are seen to shoot into this coagulated blood, the blood gradually disappears, and gelatinous matter occupies its place. This gelatinous matter progressively hardens, osseous particles are slowly deposited, and thus the fracture is ultimately repaired. During all these stages of renovation one agent appears to be principally employed, and that agent is capillary blood-vessel. It is capillary vessel which shoots into the coagulated blood, which deposits the callus, which conveys the osseous substance, and which unites the fractured bone. When muscle is divided the same process is established, excepting that fibrin is deposited instead of ossific matter; and whether the secretion be nerve or cartilage, tendon or skin, no difference can be detected in the secreting vessel, and nothing essential but secreting vessel can be discovered.

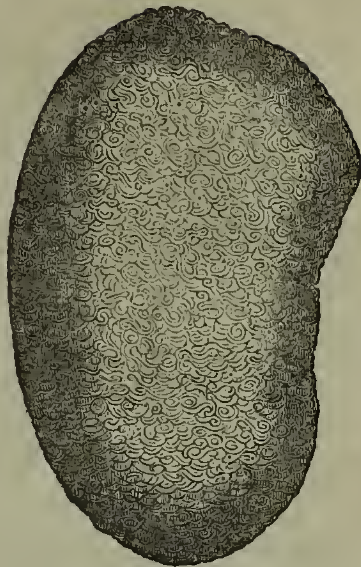
If, then, nothing but capillary blood-vessel be required to secrete such important and different substances as the animal solids, may it not be suspected that the fluids of the human body are formed in the same way, and by the same instruments? The mucus which lubricates the nostrils is secreted by a fine and highly vascular membrane, which covers them internally. The perspiration which oozes from the skin is poured out through small apertures in the walls of capillary arteries, which lie beneath the cuticle. The water which exudes from such serous membranes as the pleura, which lines the chest, or the pericardium, which surrounds the heart, seems to be filtered in the same manner through these vascular strainers from the general mass of blood. In none of all these, and in no analogous instances, can there be found any specific secreting apparatus. Capillary blood-vessel is alone discoverable.

Malpighi maintained that such glands

as the liver are composed of very small bodies, called *acini* from their resemblance to the stones of grapes; that these acini are hollow internally, and externally covered with a net-work of blood-vessels; that these minute blood-vessels covering the acini pour into the cavities of these elementary cells the secreted fluid as it is eliminated by them, out of which it is afterwards removed by ducts. The minute dissections of Ruysch, however, induced this distinguished anatomist to dissent from the views of Malpighi; and, after a series of very accurate experiments, he was satisfied that the apparently hollow acini of Malpighi are merely convoluted vessels, perfectly continuous with the excretory ducts that carry away the secreted substances. This opinion was, for a time, strongly opposed; but it afterwards became general, and is now, perhaps, universally adopted.

The chief, if not the only, difference between the secreting structure of glands and that of simple surfaces appears, then, to consist in the different number and the different arrangement of their capillary vessels. The actual secreting organ is in both cases the same—capillary blood-vessel; and it is uncertain whether either its peculiar arrangement, or greater extent in glandular texture, be productive of any other effect than that of furnishing the largest quantity of blood-vessel within the smallest space. Thus convoluted and packed up, secreting organ can be procured to any amount that may be required, without the inconveniences of weight and bulk. These acini are most distinctly seen in the liver and spleen; in the pancreas and kidneys they are less perceptible; and in the prostate and tonsils they cannot be detected by the finest glasses. Glandular structure has accordingly been arranged into three varieties. In the first are placed all those glands which are uniform in their external surface; which are composed internally of acini, bound together by cellular tissue, and which are enclosed in a general membrane. The *liver* affords a good illustration of this form of gland. In whatever part it may be examined, its texture appears uniformly the same. Nothing but acini can be seen—there are no larger and no smaller subdivisions; and when the structure of one acinus has been fully ascertained, the composition of the entire organ is understood. The anatomy of the second variety is somewhat dif-

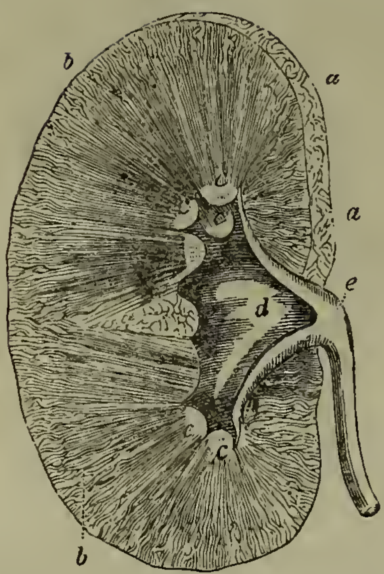
Fig. 79.



This figure represents the human kidney, which is so finely injected, that what were considered acini or hollow globules by Malpighi, appear to be merely convoluted vessels.

ferent. The glands pertaining to this order are obviously composed of subordinate divisions called *lobes*, which themselves consist of subdivisions called *lobules;* these lobules are formed of smaller bodies, which are again divisible into bodies still smaller, until we ultimately arrive at the elementary acini, which are, in common with the first class of glands, the rudimental constituents of the second class. As a fine example of this glandular tissue, the *kidney* may be taken. When viewed externally, it is manifestly lobulated, and its internal structure is strikingly beautiful. It consists of two distinct varieties of texture, —the first, being external, is called *cortical,* and the second, from its office, is denominated *tubular*. The cortical portion is the secreting organ of the kidney; the tubular portion is mainly composed of tubes, which convey the urine formed within the cortical tissue into the reservoir, or *pelvis,* of the kidney. These tubes are at first, where they issue from the cortical substance, very small and numerous; but they increase by uniting as they proceed, and they form considerable trunks before they terminate in the small oval projections called *papillæ, c c c c*. These papillæ, which are formed by the union of the uriniferous tubes, project into, and are surrounded by membranous cups called

Fig. 80.



The interior of the human kidney: *a a*, the cortical portion; *b b*, the tubular portion; *c c c c*, the papillæ; *d*, the pelvis; *e*, the ureter.

calyces, which receive the urine poured out by the papillæ from the extremities of the tubes, and convey it onwards to the pelvis or basin of the kidney, from which it is conducted by an excretory duct, styled *ureter*, into the urinary bladder.

The two varieties of glands now described, differ only in the number of their component parts, not in the nature of their composition; and, because the first form of gland consists of parts of the same size and equally elementary, while the second divides and subdivides before its rudimental structure is attained, the former is generally termed a *conglomerate*, the latter a *conglobate* gland.

The third and last form of gland is distinguished from the two preceding in having no discoverable specific structure. Without lobes, lobules, or acini, these organs exhibit neither parts nor divisions; they are dense, firm, lacerated with difficulty, and present everywhere a striking uniformity of aspect. Still they are highly vascular, and, when inflamed, produce excruciating pain; so that, in whatever other points these different forms of glandular structure may disagree, they are all equally remarkable for the profusion of blood-vessels with which they are supplied. It has been estimated that the glandular portion of the human body contains two-thirds of the entire mass of blood; and when successful injection has rendered all their vessels visible, six-eighths of their whole structure appear to be composed of capillary blood-vessels, for secreting the fluid which they are destined to elaborate, and of excretory ducts for removing that fluid as it forms. When all these facts are compared and considered, it would seem a reasonable inference that, as far as regards the vascular part of the apparatus, to constitute a secreting organ, blood-vessel alone is requisite; and that glands differ from mere secreting surfaces, as the pleura or peritoneum, chiefly in having a greater number of blood-vessels, only differently arranged. The intervening cellular tissue, by which these blood-vessels are tied up and connected, appears not to be essential, because in a mere serous membrane there is little or no such cellular tissue; nor are excretory ducts indispensable, since many glands have central apertures instead of ducts, through which their secretions are poured out. In the present imperfect state of our knowledge, it is impossible to estimate what effect difference of size, length, and direction in the secreting vessels, may exert upon the nature and quantity of the substance secreted. It is reasonable to believe that these circumstances may exert, and that they do exert, considerable influence upon the process; but, as far as regards the vascular part of the apparatus of secretion, all that is really known is told when it is stated, that wherever this function is performed, there is provided an abundant supply of capillary blood-vessels.

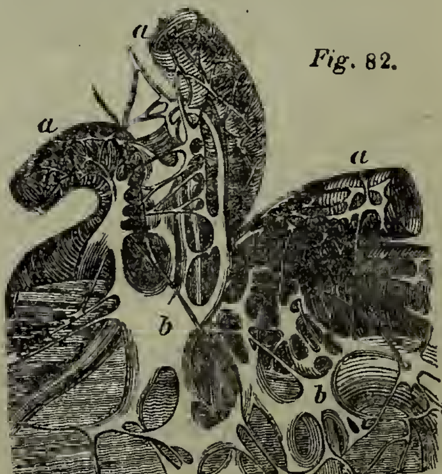
To the blood-vessels of secreting organs, as to all other parts of the body, are added nerves; and the number of nerves which are distributed to secreting organs, bears a close relation to the number of blood-vessels. If the capillary arteries are countless, so also are the ultimate nervous filaments. Moreover, there are some anatomical peculiarities in the nerves of secreting organs, which deserve to be borne in mind, because it is probable that they are intimately connected with the function of secretion. While treating of the nervous tissue, it was stated that in all the more perfectly organized animals the nervous substance is disposed in four different modes, forming four distinct parts or organs—nerves, ganglia, or appendages to particular nerves, spinal cord, and brain. With one exception,

Fig. 81.

a the splenic artery, separating into a rich variety of branches, which divide and subdivide into a number and minuteness so extraordinary, that the spleen, the gland which this artery supplies, seems to be almost entirely composed of blood-vessels.

no nerve that comes off from the brain possesses a ganglion; but every nerve that issues from the spinal cord, is provided with one or more of these knot-like bodies. What object the ganglia serve is not understood; but we know that the nerves of sensation consist of one set of filaments, that the nerves of motion consist of another set of filaments perfectly distinct from the former, and that the nerves of secretion consist of these ganglionic nerves. These ganglionic nerves are destitute of feeling, the occasional sensibility which they indicate being, probably, derived from the nerves of sensation with which they intermingle and communicate; and they are not obedient to the will. As soon as they issue from the ganglia, they proceed to the trunks of the secreting arteries,

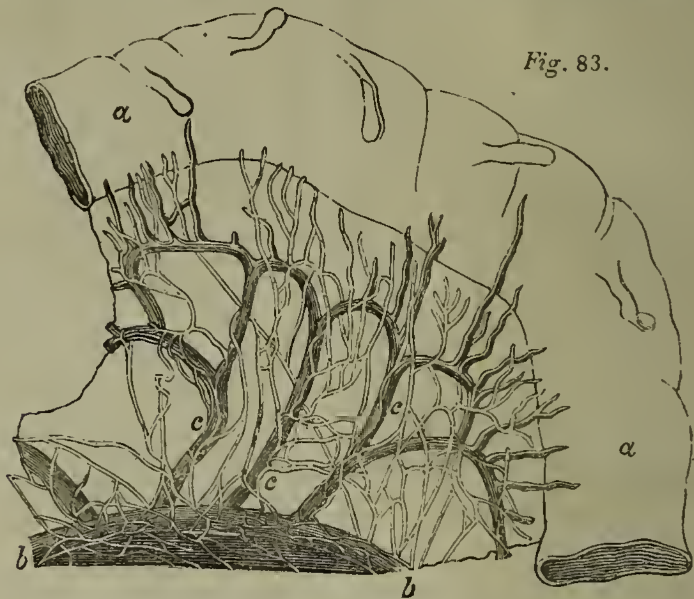
Fig. 82.



a a, blood-vessels; b b, a rich network of nerves investing the external coat of the blood-vessels.

which they invest as with a tunic, and upon the branches of which they are completely spent. That this most intimate and peculiar connexion between the ganglionic nerve and the secreting artery should exist, without functional in-

Fig. 83.



a a, a portion of intestine; *b b*, part of the abdominal aorta; *c c c*, nerves following the course of the branches sent off by the aorta to supply the intestine.

fluence being communicated to the vessel by the nerve, is scarcely to be conceived What that influence is, it is impossible to say; its extent will presently be pointed out.

Substances secreted.

Considering, then, the great simplicity of the secreting organ, and the general sameness of the blood from which every secretion is derived, it is remarkable that so many solids, so differently constituted, and such a variety of fluids, so totally dissimilar both in property and aspect, should be manufactured out of one common material, and by one common apparatus. Nothing exists within the vegetable or animal kingdom but secreted substance; and whether we look to the meanest shrub, or to the noblest animal, the most splendid variety of substance and of quality is observed. In the one kingdom we find flowers of the gaudiest colours, sweets of the most delicious taste, odours of the most captivating fragrance,—all formed out of a simple and almost insipid sap; and in the other we discover bones hard and insensible, muscles soft and contractile, nerves tender and irritable, fluids insipid, sour, bland, and acrid, juices the most agreeable, and poisons the most pernicious—all proceeding from one common fluid. Much of the food which we eat, of the dress which we wear, and of the houses which we inhabit, is derived from this source. Even light and heat, electricity and galvanism—substances the most subtile and mysterious, can be elaborated by secretion. The electrical properties of the *Torpedo* are too well known to require description. The *Elater noctilucus* shines so strongly, that many Indian tribes in South America were, at one period, said to have employed no other light for business than that which these insects emitted; and even now it is customary for their women to wear them as brilliants in their hair. The light evolved by the *Medusa pellucens* is occasionally so vivid, that water, in which these animals have been for some time confined, appears, when poured out, like a stream of fire, or of melted gold; and Spallanzani describes an individual of the same species as quite visible, by its own light, when thirty feet below the surface of water. The *Pyresoma Atlanticum* is an elongated fish, which, when floating upon the surface of the ocean, resembles a bar of incandescent iron; and the *Pennatula phosphorea* emits light so copiously, that fishermen, while at work, are said to have availed themselves of its direction.

Most of our finest dyes and of our

ctive medicines are animal secretions. The Tyrian purple, so celebrated among the ancients, is now known to have been obtained from different species of the *Gasteropoda;* the Romans employed the black fluid secreted by the cuttlefish as an ink; the Indian ink, which comes to us from China, is supposed to be the secretion of some *Sepia;* and the colour called *Sepia* by painters, is the inky fluid of this animal reduced to dryness. *Musk* is a secretion of the *Thibet musk; Castor* is obtained from a species of *Beaver;* and for *Civet* we are indebted to the *Civet-cat.*

On a former occasion, some account was given of the different solids and fluids which enter into the composition of the human body. It was then observed that, however dissimilar the former might appear, they could be arranged into three distinct classes—into cellular, muscular, and nervous solids; and that, perhaps, the least objectionable classification of the latter was into aqueous, albuminous, mucous, gelatinous, fibrinous, oleaginous, resinous, and saline fluids. The general physical and vital properties of each solid were likewise stated; the different organs into the composition of which each entered were enumerated; and the uses to which each was applicable were briefly described.

It has been usual to restrict the term Secretion to the animal fluids, but there is no reason why it should not also be applied to the solids. Bone and muscle, tendon and skin, are as different from the general mass of blood, and are as dependent upon it for their formation, as bile or mucus, tears or saliva. The secretion of urine is as essential to nutrition as that of blood-vessel, or nerve; for, although this fluid is separated from the blood in order to be expelled, while blood-vessel and nerve are separated in order to be retained, yet, did the separation of urine cease, the blood would be no longer fitted for the purposes of life, and neither nerve nor blood-vessel could any longer be deposited.

Chyme, chyle, and blood, by far the most important fluids of the body, because the source of all the rest, have been already sufficiently described; and as many of those which proceed from them have nothing interesting beyond the theory of their formation, it will not be necessary to give any further account of them here.

Theory of Secretion

The secreting organ is so simple and so uniform, the secreted substances are so dissimilar, and the blood, upon which the former operates, and from which the latter are produced, is so much alike in every part of the body, that there is little apparent correspondence between the secreting instrument and its action. Were glandular texture indispensable to secretion, and were the qualities of the secreted substances invariably connected with obvious peculiarities in the texture of the secreting organs, it might be hoped that structure would discover a key to their function. But when it is found that bodies evidently glandular, like the spleen, brain, thyroid, and lymphatic glands, eliminate no visible secretion; that glands anatomically similar elaborate secretions most opposite in character; that, while simple fluids are sometimes formed by glands, complex fluids are frequently formed without them; that, in fine, there are glands without secretions, and secretions without glands; it follows that gland and secretion can have no inseparable connexion; and that it is vain to hope to explain, by mere peculiarities of structure, either the general theory of secretion, or the individual varieties of the different secretions.

At the same time it is reasonable to believe, that structure does exert some influence on secretion. The vessels of each secreting organ differ in number and size, and they may likewise differ in direction and arrangement. The same remark is equally applicable to their nerves; and though, in the present state of our knowledge, we are unable to determine what influence such anatomical diversities may have upon secretion, that some influence is derived from them is well established. All animal secretions are formed from the blood, and, with the exception of the bile, from arterial blood; and although the blood, as has been shown, does not contain all the proximate principles that are to be detected in the animal secretions, it does contain the four elementary principles that have been described as entering into the composition of animal matter. Now, it is the object of secretion to combine and recombine these elementary principles in such different proportions as to form out of them the different substances which either the

growth or the nutrition of the body may require; and it is not improbable that one effect of structure is to bring the blood into circumstances favourable to such decompositions and such new arrangements. It is certain that two circumstances, most essential to chemical action, are, the minute division of the substances to be acted on, and the close approximation of their integrant particles. But one great aim of all the secreting organs, whether they be simple surfaces, complex glands, or in whatever mode they may be varied, seems to be to bring about this minute division, and this close approximation, of the particles of the blood which they contain. Hence the astonishing minuteness of the secreting arteries, and hence their endless inosculations with each other. It has furtner been conjectured, that in every secreting organ these minute vessels differ in the angles at which they go off from the trunk, in the course which they pursue through the glands, and in their length and size; that these differences materially affect chemical action; and that, probably, both the generation and transmission of the galvanic fluid, the agency of which in dissolving old, and in establishing new combinations is so remarkable, may partly depend upon them. These considerations, taken collectively, may, perhaps, afford us some assistance in conceiving how structure may minister to the performance of secretion, how apparently trifling variations in the secreting organ may produce most important changes in its results, how new affinities may be brought into operation, how new combinations may be formed, how new substances may be generated, and how these substances may differ from each other as much as they differ from the common fluid out of which they spring. Prout has shown that *urea* is composed of two atoms hydrogen, one atom oxygen, and one carbon; but by removing one of the atoms of hydrogen, the urea is converted into sugar; and by adding another atom of carbon, lithic acid is produced. Mucus, which is the characteristic ingredient of mucous secretion, seems to be albumen in a coagulated state. Gelatin, which is the peculiar animal matter contained in gelatinous secretions, may be formed from albumen, by digesting the latter in diluted nitric acid. Oily matter may be manufactured out of fibrin by the addition of a little oxygen, and the red particles of the blood may be converted into bile by the same process. It cannot, therefore, be denied that secretion is in part a chemical process, and that to the varying combinations and proportions of the elementary principles of the blood may be clearly traced many of the substances which are extracted from it. Still it must not be forgotten that unaided chemistry is very limited in its influence; and that some other agent must be looked for, by which these chemical operations are regulated, by which affinities are arranged, and results are determined. There is some elective principle which selects out of the general mass of blood such substances as each secreting organ stands in need of, which sends these substances to the appropriate organ, which determines the quantity sent, and which consults the periods when supply is necessary. This presiding principle is life. When the albumen of the blood is coagulated and converted into membrane, or when its fibrin is oxydated and transformed into fat, the change, in both instances, may be immediately chemical, but, remotely, it is vital.

The liver cannot secrete bile unless the elementary principles of bile be contained in the blood which it receives; and, in a chemical point of view, it is unimportant whether these principles exist in the blood generally, or only in that portion of it which supplies the liver. If they exist in the general mass of blood, it is the principle of life which determines their separation in the liver, rather than in the lungs or in the kidneys; and if they be contained exclusively by the blood devoted to the liver, it is life to which this exclusive appropriation is to be ascribed.

It is more than probable that the instrument by which this vital principle is brought to bear upon the secreting apparatus, is the nervous system: hence the close connexion which it has been seen is maintained between the capillary blood-vessel and the ultimate nervous filament. That the nervous system is the communicating medium through which life operates upon secretion, is favoured by various phenomena, and is still more strongly supported by direct experiments. Grief relieves itself by a flow of tears; hunger encourages the secretion of gastric juice; and melancholy is proverbial for accumulating bile. During the operation of

fear, the kidneys are frequently stimulated to increased activity; and the smell of food strongly excites the salivary glands. The limb which has been palsied by a stroke of apoplexy emaciates and decays; and by dividing the nerves which supply the stomach, digestion has been effectually arrested. The stomach derives its nerves chiefly from the eighth pair, or *par vagum;* and experiment has ascertained that if a portion of this nerve be removed, the process of digestion is completely stopped. Two rabbits of about the same size were fed in the same way; in both the eighth pair of nerves were brought into view; in one rabbit a part of each nerve was removed; in the other, after being raised on a probe, both nerves were replaced without further injury. After the operation, both rabbits were allowed to eat as much parsley as they chose. When the rabbit, in which part of the nerve was removed, died (which happened in about twenty hours after the operation), the other was killed. In the former the food was found wholly undigested, and could not be distinguished from parsley chopped small with a knife; but in the latter, digestion had gone on as usual, and the food was found just in the same state as in a healthy rabbit. These experiments (and they have been variously repeated) strongly favour the view that a regular supply of the influence derived from the nervous system is necessary to the process of secretion. But the curious fact is, that the absolute continuity of the nerves, through which this influence is to be transmitted, is not indispensable for its conveyance. Dr. W. Philip and Mr. Brodie state, that if the cut ends of a divided nerve be placed at a distance of not more than a quarter of an inch from each other, the current of nervous energy is not interrupted, and that the secretions of the organ to which the nerve is sent go on as usual; but that if a larger portion of the nerve be removed, so as to separate its divided extremities to a greater distance, the process of secretion is completely stopped.

It has been conjectured that this nervous influence is identical with, or at least is some modification of, the electric or galvanic fluid; and the arguments by which this conjecture is supported are ingenious, if not strong. Too little, however, is as yet known upon this point to sanction any inference; and there are some who feel strongly inclined to question altogether the interference of the nervous system in the process of secretion. It is certain that the mole, or imperfect child, which has no nervous system, attains a very considerable size; that a palsied limb can inflame and suppurate; and that the nostril and ear of the palsied side secrete as actively as those of the sound side. These and many analogous facts are well known; and if secretion can in any case be performed without nerves, or after the nerves which do exist have lost their power by disease, the doctrine, which holds nervous energy to be indispensable to this function, is not, perhaps, sufficiently established; while, at the same time, it cannot be denied, that no other view is in the abstract more plausible, or, when applied to life, can illustrate a greater variety of phenomena.

Absorption.

It has been more than once observed that a constant round of expenditure and supply is absolutely necessary to the continuance of existence. Parts and organs, which are healthy and in great requisition at one period of life, become injurious or useless at another; new functions are silently establishing themselves upon the ruins of the old; and the changing circumstances, through which man passes during his journey from tender infancy to decrepit age, are faithfully met by corresponding and suitable alterations in his structure. To have those substances which are secreted taken up and removed, when they are no longer necessary, is, therefore, as essential as to have them at first secreted; and a new function, called *absorption*, has been established for this purpose. Nutrition is the compound result of secretion and absorption, and the derangement of either is equally injurious. In fever absorption is much more active than secretion; hence rapid emaciation is one of the most striking features of that disease: while, in dropsy, more matter is deposited by the arteries than the absorbents can remove. To preserve these two functions in a state of balance is the design of Nature; so that no more matter may be secreted than can be absorbed, nor absorbed than can be secreted. When thus equipoised in activity, these two opposing systems co-operate to the same effect—nutrition; one particle succeeds another in slow and silent renovation; every part of the animal fabric is gradually withdrawn, and is as gradually rebuilt; and without the disturbance of a

function, or the inconvenience of a tissue, this scientific masonry proceeds until the old building is carefully pulled down, and wholly reconstructed.

The apparatus, by which absorption is performed in the human body, consists of three parts,—lacteals, lymphatics, and absorbent glands. These three sets of organs compose a distinct system, denominated the *absorbent system*, which, from its exceeding minuteness, and the consequent difficulty of investigating its structure and laws, was almost entirely unknown until the beginning of the seventeenth century. The lacteals and lymphatics are, in structure, aspect, and function, essentially the same vessels. Both arise and terminate in the same manner, both are equally minute, both absorb their contents by the same principle, both circulate them by the agency of the same power, and both carry them to the same place of destination. But as the fluid which the lacteals contain resembles milk, being the chyle which is digested from the food, while that which the lymphatics circulate is not unlike water, and principally consists of refuse matter that is no longer adapted to the purposes of nutrition, these two sets of vessels are not only differently denominated, but in general receive separate and distinct descriptions.

Both lymphatics and lacteals are composed of two coats—an outer coat, which is not unlike the external covering of a vein, and an internal coat, which is dense, smooth, and polished. Between these two tunics some have supposed a third to intervene, analogous to the muscular coat of arteries; but the existence of such a coat has been rather inferred, because considered necessary, than proved by having been actually seen.

The internal coat is firm and strong, and is thrown into crescentic folds which, as in veins, perform the office of valves. These valves occur in pairs, are extremely numerous, and give to the absorbents that knotted and irregular appearance for which they are remarkable; every knot or enlargement indicating the presence of a pair of valves. Another obvious peculiarity of these vessels is their general uniformity of size. When an artery sends off a branch, it is sensibly diminished, or when a vein receives a branch, it is enlarged; but when a lymphatic or lacteal ramifies little change of size, in general, occurs, whether the branch given off be large or small. (*Fig.* 84.)

Fig. 84.

This figure represents the uniform size and the general appearance of the lymphatic vessels: *a a a a*, lymphatics in different stages of their progress towards the thoracic duct; *b b*, an absorbent gland, through which two of the lymphatics pass; the course of their contents is indicated by the direction of the arrows.

The *lymphatics* arise by very minute orifices from every surface of the body—from the peritoneum which lines the abdomen, from the pleura which surrounds the lungs, from the membranes which encompass the brain, from the mucous surface of the trachea, œsophagus, and stomach, from the external and internal surfaces of all the viscera, and from the external skin. (*Fig.* 85).

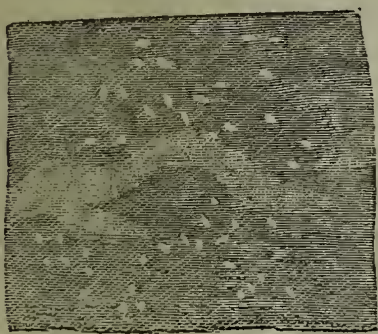
Fig. 85.

A portion of skin, the cuticle being removed, showing how the absorbents rise from it by open mouths.

They likewise arise from the interior of all cavities, from the surface of muscles, and, in fine, from every part of the body which is organized and supplied by blood-vessels. Like veins, the lymphatics are divided into two distinct sets. One set lie immediately beneath the skin, and may be easily rendered visible by injection with quicksilver; the other set are more deeply situated, and are devoted to the more internal parts of the body. These two orders of vessels inosculate freely with each other, and are similar in size, structure, and aspect.

The *lacteals* constitute a small but most important part of the absorbent system. They take their origin exclusively from the stomach and from the intestinal canal. The mucous or inter-

Fig. 86.

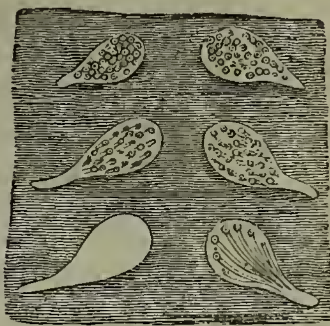


The appearance of the lacteals as they arise from the surface of the intestines, being white as milk.

nal coat of the intestines, in which the orifices of the lacteals are found, has a soft and fleecy surface, which is covered with small elevations called villi, not unlike the pile of velvet. Each of these villi seems to be composed of an artery, a vein, nerves and lacteals bound together by cellular tissue. Internally they are divided into cells, and they are exquisitely sensible, especially to the stimulus of chyle. They are extremely numerous in the duodenum, the jejunum and ileum; less so in the cœcum, and colon; and their number is still smaller in the stomach and the rectum. Liberkuhn states, that by means of the microscope it may be shewn that each villus terminates in what he calls an *ampullula*, which is an oval vesicle, having its apex perforated by lacteal orifices, through which the chyle, during its passage along the intestines, is taken up. (*Figs.* 87 and 88.)

Two distinct sets of lacteals can be discovered upon the intestines. The first, or external set, lie immediately under the peritoneal coat, and run along the gut in a longitudinal direction; the second, or deep-seated set, lie beneath the muscular coat, and following the course of the arteries and veins ramify, like them, with great minuteness, two lacteals in general accompanying each (*fig.* 87) artery. At first, these two sets

Fig. 87.



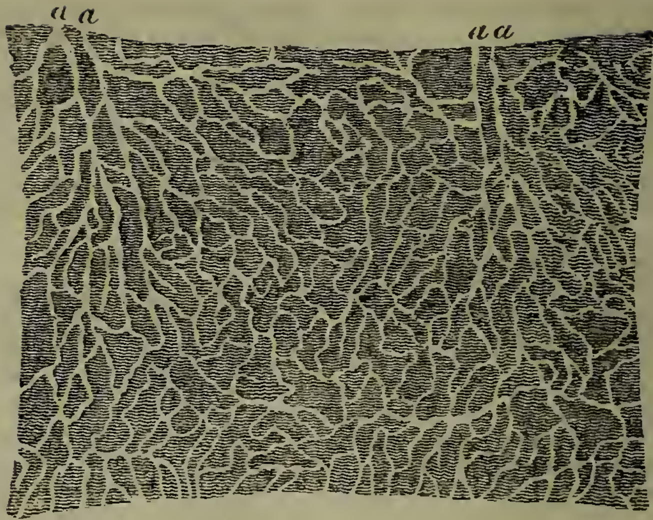
This figure represents the villi as they appear when viewed through the microscope: the orifices of the lacteals are seen distinctly; the lowermost villus so turgid with chyle that no orifices are apparent.

Fig. 88.

Two ampullulæ magnified, turgid with chyle.

of vessels run at right angles with each other, but after the superficial lacteals have proceeded some length along the intestine, they turn up at an angle more or less acute, towards the mesentery, where they unite with the circular or deep-seated lacteals; after which they all ascend together, until meeting in their course with some absorbent gland, they enter its substance, and after passing through it, and uniting into one or two large trunks, they again issue from its opposite extremity, and prosecute their way towards the thoracic duct. In the adjoining figure, (*fig.* 90,) all these particulars are beautifully illustrated. A A, is a piece of the jejunum; *b b b b*, &c. are the superficial lacteals; *c c c*, is the mesentery by which the intestines are confined to the spine, and within the folds of which the deep-seated lacteals pass; *d d d*, the first order of the absorbent glands; *e e e*, the second order, through which the trunks that issue from the first order

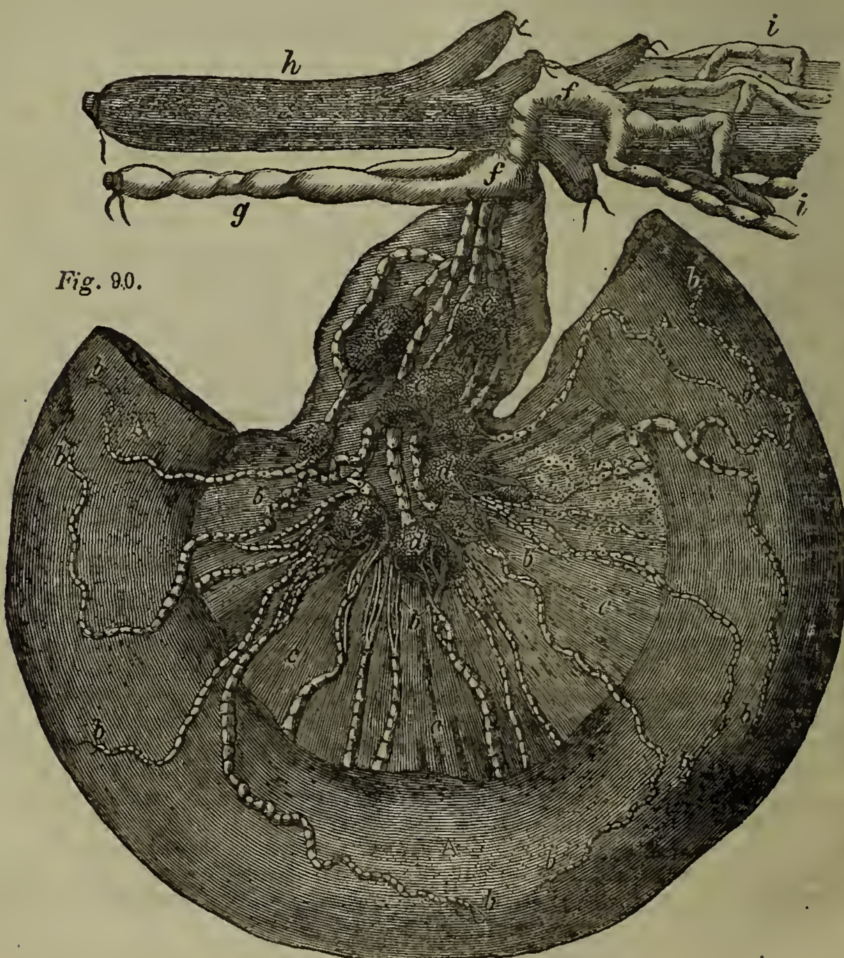
Fig. 89.



a a, a a, four lacteal trunks, formed by an infinity of smaller lacteals, which arise from every part of the surface of the intestine.

pass; *ff*, the receptaculum chyli, or commencement of the thoracic duct; *g*, the thoracic duct; *i i*, lymphatics coming from different parts of the body,

Fig. 9.0.



and uniting to form the receptaculum chyli; *h*, the aorta.

The thoracic duct, *g*, or great trunk of the absorbent system, is formed by the union of the lacteal trunks with the two large lymphatic vessels which have been before described. The duct, at its commencement, is generally somewhat larger than at any other part, and this enlargement has received the name of *receptaculum chyli*, (or receptacle of the chyle *f f*); which varies very much in size, being in some instances scarcely perceptible, while in others it has been found no less than half an inch in diameter. This receptacle is situated upon the second or third vertebra of the loins, and the duct, as it issues from it, lies beneath the right arch of the diaphragm. After getting from under this muscle, it proceeds, in company with the aorta, along the right side of the spine, until it reach the fifth vertebra of the back; where it passes over to the left side of the spine behind the œsophagus. It then, ascending behind the left carotid artery, runs up to the interstice between the first and second vertebræ of the chest, where, after receiving the lymphatics which come from the left arm, and left side of the head and neck, it suddenly turns downwards, and finally terminates in the angle formed by the meeting of the subclavian and internal jugular veins of the left side.

As the general structure of glands has been already described, it will he necessary to add but little in relation to the anatomy of those which belong to the absorbent system. In form they are not unlike an olive, being oval or oblong. They are enclosed within an envelope of condensed cellular substance, and they are generally so situated, as to have their long axis placed in the same line with the vessels which pass through them. This investing membrane is so loosely attached to them, that tolerably free motion is allowed, and its cavity contains some viscid fluid. Some anatomists assert, that these bodies consist of convoluted vessels, while others maintain, with greater plausibility, that their internal structure is cellular. They are found in the greatest number in the neighbourhood of joints; they are very susceptible of disease, and since the absorbents pass through them in their progress to the thoracic duct, it is obvious that any important change in their structure must be productive of the most serious consequences, by retarding or diminishing the supply of chyle.

Theory of Absorption.

The outline, brief as it is, which has now been given of the anatomy of the absorbent system, will enable us to understand the course which the substances absorbed take in their journey to the heart. The lymphatics, arising by small and imperceptible mouths from every tissue of the body, and the lacteals, from the internal surface of the alimentary canal, take up the different substances they are destined to ahsorb, conveying them to one or other of the great absorbent trunks which have been described, and hy those trunks pour their contents either into the left or the right subclavian vein. In this manner, provision is made for furnishing the function of secretion with a constant and adequate supply of material: whence it happens that, although secretions the most expensive to the system are daily and hourly elaborated, and the heart is every moment drained of its blood, yet the supply of chyle by the lacteals, and of lymph by the lymphatics, is so liberal and so regular, that the former can never fail through deficiency of fluid, nor the latter cease to act in consequence of being permanently emptied.

It becomes, then, a question of curious interest, by what power do the lacteals and lymphatics take up, in different parts of the body, those substances which they are designed to remove, and convey to the heart the substances they receive. There is here no forcing organ like the heart; there are no strong and muscular vessels like the arteries. Arising by small and almost invisible twigs from bone and muscle, from membrane and fat, and after a long and circuitous course through many opposing obstacles, at length terminating in a vein at some distance from the heart, it is obvious that the latter organ can exert but little influence upon the action of the absorbent vessels, and that neither the suction power of its right cavities, nor the propelling power of its left, can materially assist the ascent of the contents of the absorbents into the subclavian vein. It has been stated, that the supposed muscularity of the absorbents has never yet been demonstrated; and the doctrine, that their extremities are continuous with those

of the blood-vessels, in consequence of which the lymph is conceived to be propelled along the lymphatics, in virtue of the *vis a tergo* of the heart and arteries, is inadequate to explain the function, both because such continuity does not exist, and because, if it did, it could not account for the motion of the chyle in the lacteals, vessels which arise by open mouths from the surface of the intestines.

That capillary attraction has some share in the performance of absorption, is, we think, unquestionable; for after life is extinct, and after every living agent has ceased to act, the lacteals have been often seen not only full of chyle, but carrying their chyle actively forward towards the thoracic duct. This phenomenon can be accounted for only on the supposition, that the lacteals are, to a certain extent, capillary vessels, and that they can convey the chyle which they contain a certain length in virtue of their capillary power; hence, probably, the care that has been taken to confine the diameter of the absorbent vessels within a certain magnitude, and to furnish them abundantly with valves. Still, however, it is uncertain how far their capillary power extends, and to what degree it operates—the size of the thoracic duct, without doubt, incapacitating it for exerting such a power, and there is reason to believe that this, the more difficult part of absorption, is accomplished by some less mechanical and more efficient agency.

It has been already stated that both lacteals and lymphatics, before arriving at the thoracic duct, invariably pass through one or more conglobate glands; that the internal structure of these glands is cellular, and that the villi of the mucous membrane of the intestines terminate in vesicles called *ampullulæ*, which, like the absorbent glands, are composed of cells. These are anatomical facts: it has long been a subject of inquiry why the absorbent vessels should so universally and invariably pass through one or more of these glands, although, in order to do so, it is often necessary that they should deviate from their direct course. It is well known, that the capillary roots of trees, and other plants, are terminated by small oval bodies called *spongiolæ;* that if these spongiolæ be removed, the roots to which they are attached lose their absorbing power, and that the vegetable dies. It is likewise known that these spongiolæ are composed of cells, which are covered with a membranous envelope that contains some fluid, and it has been lately discovered by Dutrochet, a French physiologist of distinction, that these spongiolæ absorb nutritive fluid from the soil which surrounds them, in virtue of a principle which he has denominated *endosmose.* That this principle may operate with energy three conditions are necessary: First, that the absorbing medium be an organized vegetable or animal membrane; secondly, that there be a fluid enclosed within this membrane; and thirdly, that this internal fluid be denser than the fluid without, which is to be absorbed. By many very able and ingenious experiments Dutrochet has ascertained, that if these three conditions be observed, a power is generated which can raise fluid up a tube of any height, with a velocity proportional to the excess of the density of the interior over the exterior fluid. Into an instrument, which he calls an *endosmometer*, Dutrochet put a solution of sugar, of the density of 1.110, and immersed the end of the instrument in water. In two days, twenty-two inches of a column of mercury, the base of which was equal in diameter to the piece of bladder which was the absorbing membrane employed, was raised to a height of 45 inches and 9 lines; and the general conclusion to which the author arrives, after a great many arguments, facts, and experiments, which we can here merely refer to; is that by means of a common endosmometer, such as he employed, a syrup made of sugar, of the density 1.3, would generate an endosmosmic force sufficient to raise a weight equal to four atmospheres and a half. Now, it is by no means improbable, that the absorbent glands are living endosmometers. Like spongiolæ, they are composed of cells; these cells are surrounded by a membrane, and this membrane contains a viscid fluid. The three conditions necessary to generate endosmose are, therefore, present and complete. The ampullulæ, which are attached to the extremities of the villi, and on which the lacteals open, are similarly constructed, and, probably, act by the agency of the same principle; and although the orifices of the lymphatics are as yet unknown, analogy perhaps warrants the conclusion, that they do not, in this respect, essentially differ from the lacteals, which, in all other points, they closely resemble.

From some experiments which have been made with the voltaic pile, it would seem that this endosmosmic function, however, is intimately connected with galvanic electricity; but want of space precludes us from further detail.

Substances absorbed.

As has been already stated, the principal fluid which the lacteals absorb is chyle, while the variety of substances upon which the lymphatics act is great. Fluids of every consistence, solids of every texture, substances without as well as within the body, the hard bone and the soft brain, are alike decomposed and gradually removed. The rapidity with which their function is in some cases performed is remarkable. Thus, a few minutes after swallowing turpentine, the urine smells strongly of the odour of violets. In some forms of disease emaciation proceeds with astonishing rapidity; cases of dropsy not unfrequently occur, in which most extensive accumulations of water are removed in a few hours; it must be familiar to every one how soon, after drinking plentifully of some diluting beverage, the kidneys are excited to increased activity.

In all these instances the substances absorbed have either been in a fluid state, or soft, and easily broken down; and the action necessary to accomplish their removal does not seem so extraordinary as that which affects the absorption of bone, enamel, and other such hard animal formations. Still, however, bone and enamel are as easily, and as regularly absorbed as the most limpid fluids. In young animals the long bones are nearly solid, but those of old animals have a considerable internal cavity; the osseous matter in the interior of the young bone having been gradually removed at a more advanced period of life. When a portion of bone dies, or becomes carious as it is termed, ossific particles are deposited round the diseased bone, until an entirely new bone is formed, and the old bone, which is then included within the new, is completely removed by absorption. How structure so hard and imperishable can be so easily decomposed, and so finely comminuted as to be capable of entering such delicate vessels as the lymphatics, it is difficult to conceive, but it is probable that some chemical agent is at first employed, and that the absorbents begin to operate upon the substances they remove, only after the subtle chemistry of the animal economy has prepared them for their action.

Excretion

It appears, then, that the substances within the agency of the absorbent system consist of two classes. To the first belong all those substances which are denominated *recrementitious*, because they are more or less nutritive, and are fitted to maintain life; to the second, or the *excrementitious*, belong those which are exhausted, or injurious. Both are poured indiscriminately into the general circulation; the former are retained for the purposes of nutrition, and the latter are sent to the different excretory organs, to be there separated from the blood, and finally to be conveyed out of the system. Some of these effete substances are carried to the kidneys, and others to the intestines; while some are excreted in the form of bile, and others in that of perspirable matter. In this manner every animal particle is disposed of with rigid economy; nothing which can serve any useful purpose to the system is wasted; nothing which might prove noxious is retained, and every function, whether vital or animal, whether secretory or excretory, is thus made conducive to the support, the safety, or the pleasure of existence.

Conclusion.

We have now completed our account of an extended circle of actions of great importance in the animal economy. After having considered the phenomena peculiar to life, the character by which the animal is distinguished from the vegetable, the common tissues which enter into the composition of the human body, and the properties possessed by each; we have traced the series of changes by which a morsel of food, when received by the mouth, is converted into blood, and the subsequent processes by which it is rendered a constituent part of the body, and as soon as it has performed its office, is removed out of the system, in order to make room for new matter. To accomplish these objects, the requisite circle of functions comprehends, as we have seen, 1st, Digestion, by which the food is converted into chyle; 2dly, Respiration, by which the chyle is converted into arterial blood; 3dly, Circu-

LATION, by which the arterial blood is conveyed from the left side of the heart to the system, and returned from the system to the right side of the heart; 4thly, SECRETION, by which new particles eliminated from the blood are deposited, when formed, by the capillary vessels, and by which the body is maintained in a state of perpetual renovation; 5thly, ABSORPTION, by which the old particles are taken up as the new are laid down; and lastly, EXCRETION, by which old particles, that have served their office in the economy, are conveyed out of the system.

Of the apparatus by which these varied processes are performed, as well as of the processes themselves, we have given a brief account, which we have endeavoured to render intelligible to the reader; though we have been sometimes embarrassed by the difficulty of making known by description objects which cannot be well understood without being seen. Varied as the processes are, and numerous as we have seen the organs to be by which they are performed, yet it is obvious that they complete but one function—that of nutrition; and that they accomplish but one object—the preservation of the individual. The account of this circle of actions, therefore, by no means comprehends the entire science of physiology, which includes further the functions of locomotion, the functions termed the nervous, the sensorial, and the intellectual, and, finally, the function of reproduction. It is obvious that the former constitute the higher department of the science of physiology, to the consideration of which, it is possible, we may return at some future period.

However brief and incomplete the sketch here given of this science may be, yet it may at least suffice to convey a distinct conception of the nature of the phenomena of which it is its province to treat. In no other department of knowledge are the facts unfolded so curious, and in few are they of greater practical value. To shut out the fund of information it contains from all who do not devote themselves to the medical profession, is as unreasonable as it would be to exclude the knowledge of chemistry from every one but the practical pharmaceutist. This treatise will not have been written in vain, if it should do no more than shew that the science of life is perfectly open to the student of nature, to the cultivation of which he may approach without the apprehension of meeting with any extraordinary difficulties. The obvious and peculiar advantages of this kind of knowledge are, that it would enable its possessor to take a more rational care of his health; to perceive why certain circumstances are beneficial or injurious; to understand in some degree the nature of disease, and the operation as well of the agents which produce it, as of those which counteract it; to observe the first beginnings of deranged function in his own person; to give to his physician a more intelligible account of his train of morbid sensations as they arise; and above all, to co-operate with him in removing the morbid state on which they depend, instead of defeating, as is now, through gross ignorance, constantly done, the best concerted plans for the renovation of health. It would likewise lay the foundation for the attainment of a more just, accurate, and practical knowledge of our intellectual and moral nature. There is a physiology of the mind as well as of the body; both are so intimately united, that neither can be well understood without the study of the other; and the physiology of man comprehends both. Were even what is already known of this science, and what might be easily communicated, made a part of general education, how many evils would be avoided, how much light would be let in upon the understanding, and how many aids would be afforded to the acquisition of a sound body and a vigorous mind;—pre-requisites more important than are commonly supposed, to the attainment of wisdom and the practice of virtue.

ANIMAL MECHANICS,

OR,

PROOFS OF DESIGN IN THE ANIMAL FRAME.

THE PERFECTION OF DESIGN IN THE BONES OF THE HEAD, SPINE, AND CHEST, SHOWN BY COMPARISON WITH ARCHITECTURAL AND MECHANICAL CONTRIVANCES.

Introduction.

To prepare us for perceiving design in the various internal structures of an animal body, we must first of all know, that perfect security against accidents is not consistent with the scheme of nature. A liability to pain and injury only proves how entirely the human body is formed with reference to the mind; since, without the continued call to exertion, which danger and the uncertainty of life infer,—the development of our faculties would be imperfect, and the mind would remain, as it were, uneducated.

The contrivances (as we should say of things of art) for protecting the vital organs are not absolute securities against accidents; but they afford protection in that exact measure or degree calculated to resist the shocks and pressure to which we are exposed in the common circumstances of life. A man can walk, run, leap, and swim, because the texture of his frame, the strength and power of his limbs, and the specific gravity of his body are in relation with all around him. But, were the atmosphere lighter, the earth larger, or its attraction more—were he, in short, an inhabitant of another planet, there would be no correspondence between the strength, gravity, and muscular power of his body, and the elements around him, and the balance in the chances of life would be destroyed.

Without such considerations the reader would fall into the mistake, that weakness and liability to fracture imply imperfection in the frame of the body, whereas a deeper contemplation of the subject will convince him of the incomparable perfection both of the plan and of the execution. The body is intended to be subject to derangement and accident, and to become, in the course of life, more and more fragile, until, by some failure in the frame-work or vital actions, life terminates.

And this leads us to reflect on the best means of informing ourselves of the intention or design shown in this fabric. Can there be any better mode of raising our admiration than by comparing it with things of human invention? It must be allowed, that we shall not find a perfect analogy. If we compare it with the forms of architecture—the house or the bridge are not built for motion, but for solidity and firmness, on the principle of gravitation. The ship rests in equilibrium prepared for passive motion, and the contrivances of the ship-builders are for resisting an external force: whilst in the animal body we perceive securities against the gravitation of the parts, provisions to withstand shocks and injuries from without, at the same time that the framework is also calculated to sustain an internal impulse from the muscular force which moves the bones as levers, or, like a hydraulic-engine, propels the fluids through the body.

As in things artificially contrived, lightness and motion are balanced against solidity and weight, it is the same in the animal body. A house is built on a foundation immoveable, and the slightest shift of the ground, followed by the ruin of the house, brings no discredit on the builder; for he proceeds on the certainty of strength from gravitation on a fixed foundation. But a ship is built with reference to motion, to receive an impulse from the wind, and to move through the water. In comparison with the fabric founded on the fixed and solid ground, it becomes subjected to new influences, and in proportion as it is fitted to move rapidly in a light

breeze, it is exposed to founder in the storm. A log of wood, or a Dutch dogger almost as solid as a log, is comparatively safe in the trough of the sea during a storm—when a bark, slightly built and fitted for lighter breezes, would be shaken to pieces: that is to say, the masts and rigging of a ship (the provisions for its motion) may become the source of weakness, and, perhaps, of destruction; and safety is thus voluntarily sacrificed in part, to obtain another property of motion.

So in the animal body: sometimes we see the safety of parts provided for by strength calculated for inert resistance; but when made for motion, when light and easily influenced, they become proportionally weak and exposed, unless some other principle be admitted, and a different kind of security substituted for that of weight and solidity: still a certain insecurity arises from this delicacy of structure.

We shall afterwards have occasion to show that there is always a balance between the power of exertion and the capability of resistance in the living body. A horse or a deer receives a shock in alighting from a leap; but still the inert power of resisting that shock bears a relation to the muscular power with which they spring. And so it is in a man: the elasticity of his limbs is always accommodated to his activity; but it is obvious, that in a fall, the shock, which the lower extremities are calculated to resist, may come on the upper extremity, which, from being adapted for extensive and rapid motion, is incapable of sustaining the impulse, and the bones are broken or displaced.

The analogy between the structure of the human body and the works of human contrivance, which we have to bring in illustration of the designs of nature, is, therefore, not perfect: since sometimes the material is different, sometimes the end to be attained is not precisely the same; and, above all, in the animal body a double object is often secured by the structure or framework, which cannot be accomplished by mere human ingenuity, and of which, therefore, we can offer no illustration strictly correct.

However ingenious our contrivances may be, they are not only limited, but they present a sameness which becomes tiresome. Nature, on the contrary, gives us the same objects of interest, or images of beauty, with such variety, that they lose nothing of their influence and their attraction by repetition.

If the reader has an imperfect notion of design and providence, from a too careless survey of external nature, and the consequent languor of his reflexions, we hope that the mere novelty of the instances we are about to place before him, may carry conviction to his mind; for we are to draw from nature still, but in a field which has been left strangely neglected, though the nearest to us of all, and of all the most fruitful.

Men proceed in a slow course of advancement in architectural, or mechanical, or optical sciences; and when an improvement is made, it is found that there are all along examples of it in the animal body, which ought to have been marked before, and which might have suggested to us the improvement. It is surprising that this view of the subject has seldom, if ever, been taken seriously, and never pursued. Is the human body formed by an all-perfect Architect, or is it not? And, if the question be answered in the affirmative, does it not approach to something like infatuation, that possessing such perfect models as we have in the anatomy of the body, we yet have been so prone to neglect them?

We undertake to prove, that the foundation of the Eddystone lighthouse, the perfection of human architecture and ingenuity, is not formed on principles so correct, as those which have directed the arrangement of the bones of the foot; That the most perfect pillar or kingpost is not adjusted with the accuracy of the hollow bones which support our weight; That the insertion of a ship's mast into the hull is a clumsy contrivance compared with the connexions of the human spine and pelvis; And that the tendons are composed in a manner superior to the last patent cables of Huddart, or the yet more recently improved chain-cables of Bloxam.

Let us assume that the head is the noblest part; and let us examine the carpentry and architectural contrivances exhibited there.

But, before we give ourselves up to the interest of this subject, it will gratify us to express our conviction, that the perfection of the plan of animal

bodies, the demonstration of contrivance and adaptation, but more than these, the proof of the continual operation of the power which originally created the system, are evinced in the property of life,—in the adjustment of the various sensibilities,—in the fine order of the moving parts of the body,—in the circulation of living blood,—in the continual death of particles, and their removal from the frame,—in the permanence of the individual whilst every material particle of his frame is a thousand times * changed in the progress of his life. But this is altogether a distinct inquiry, and we are deterred from touching upon it, not more from knowing that our readers are not initiated into it, than from the depth and very great difficulty of the subject.

Chapter I.

Architecture of the Skull.

It requires no disquisition to prove that the brain is the most essential organ of the animal system, and being so, we may presume that it must be especially protected. We are now to inquire how this main object is attained?

We must first understand that the brain may be hurt, not only by sharp bodies touching and entering it, but by a blow upon the head which shall vibrate through it, without the instrument piercing the skull. Indeed, a blow upon a man's head, by a body which shall cause a vibration through the substance of the brain, may more effectually deprive him of sense and motion than if an axe or a sword penetrated into the substance of the brain itself.

Supposing that a man's ingenuity were to be exercised in contriving a protection to the brain, he must perceive that if the case were soft, it would be too easily pierced; that if it were of a glassy nature, it would be chipped and cracked; that if it were of a substance like metal, it would ring and vibrate, and communicate the concussion to the brain.

Further thoughts might suggest, that whilst the case should be made firm to resist a sharp point, the vibrations of that circular case might be prevented by lining it with a softer material; no bell would vibrate with such an incumbrance; the sound would be stopped like the ringing of a glass by the touch of a finger.

If a soldier's head be covered with a steel cap, the blow of a sword which does not penetrate will yet bring him to the ground by the percussion which extends to the brain; therefore, the helmet is lined with leather, and covered with hair; for, although the hair is made an ornament, it is an essential part of the protection: we may see it in the head-piece of the Roman soldier, where all useless ornament being despised as frivolous, was avoided as cumbrous.

We now perceive why the skull consists of two plates of bone, one external, which is fibrous and tough, and one internal, dense to such a degree that the anatomist calls it *tabula vitrea* (the glassy table.)

Nobody can suppose this to be accidental. It has just been stated, that the brain may be injured in two ways: a stone or a hammer may break the skull, and the depressed part of the bone injure the brain; whilst, on the other hand, a mallet struck upon the head will, without penetrating, effectually deprive the brain of its functions, by causing a vibration which runs round the skull and extends to every portion of its contents.

Were the skull, in its perfect or mature state, softer than it is, it would be like the skull of a child; were it harder than we find it is, it would be like that of an old man. In other words, as in the former it would be too easily pierced, so, in the latter, it would vibrate too sharply and produce concussion. The skull of an infant is a single layer of elastic bone; on the approach to manhood it separates into two tables; and in old age it again becomes consolidated. During the active years of man's life the skull is perfect: it then consists of two layers, united by a softer substance; the inner layer is brittle as glass, and calculated to resist anything penetrating; the outer table is tough, to give consistence, and to stifle the vibration which would take place if the whole texture were uniform and like the inner table.

* The old philosophers gave out that the human body was seven times changed during the natural life. Modern discoveries have shown that the hardest material of the frame is changing continually; that is, every instant of time, from birth to death.

The alteration in the substance of the bones, and more particularly in the skull, is marvellously ordered to follow the changes in the mind of the creature, from the heedlessness of childhood to the caution of age, and even the helplessness of superannuation.

The skull is soft and yielding at birth; during childhood it is elastic, and little liable to injury from concussion; and during youth, and up to the period of maturity, the parts which come in contact with the ground, are thicker, whilst the shock is dispersed towards the sutures (the seams or joinings of the pieces), which are still loose. But when, with advancing years, something tells us to give up feats of activity, and falls are less frequent, the bones lose that nature which would render concussion harmless, and at length the timidity of age teaches man that his structure is no longer adapted to active life.

We must understand the necessity of the double layer of the skull, in order to comprehend another very curious contrivance. The sutures are the lines of union of the several bones which form the *cranium**, and surround and protect the brain. These lines of union are called *sutures* (from the Latin word for *sewing*), because they resemble seams. If a workman were to inspect the joining of two of the bones of the cranium, he would admire the minute dove-tailing by which one portion of the bone is inserted into, and surrounded by, the other, whilst that other pushes its processes or juttings out between those of the first in the same manner, and the fibres of the two bones are thus interlaced, as you might interlace your fingers. But when you look to the internal surface, you see nothing of this kind; the bones are here laid simply in contact, and this line by anatomists is called *harmonia*, or harmony: architects use the same term to imply the joining by masonry. Whilst the anatomists are thus curious in names, it is provoking to find them negligent of things more interesting. Having overlooked the reason of the difference in the tables of bone, they are consequently blind to the purpose of this difference of the outward and inward part of a suture.

* *Cranium*, from a Greek word signifying a helmet. The cranium is the division of the skull appropriated to the protection of the brain; it consists of six bones—the *frontal* (or forehead); two *parietal* (walls or side bones); the *occipital* (back of the head); and two *temporal* (or temple) bones.

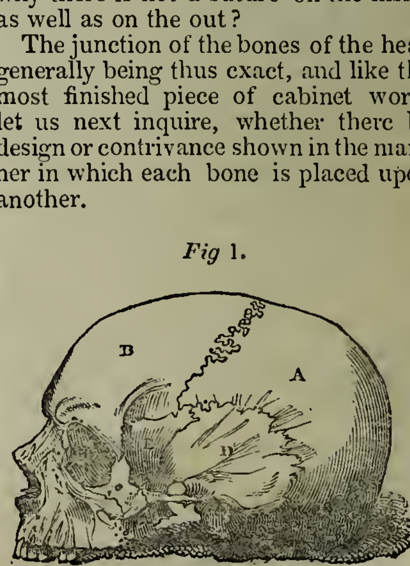
Suppose a carpenter employed upon his own material, he would join a box with minute and regular indentations by dovetailing, because he knows that the material on which he works, from its softness and toughness, admits of such adjustment of its edges. The processes of the bone shoot into the opposite cavity with an exact resemblance to the foxtail wedge of the carpenter—a kind of tenon and mortice when the pieces are small.

But if a workman in glass or marble were to inclose some precious thing, he would smooth the surfaces and unite them by cement, because, even if he could succeed in indenting the line of union, he knows that his material would chip off on the slightest vibration. The edges of the marble cylinders which form a column are, for the same reason, not permitted to come in contact; thin plates of lead are interposed to prevent the edges, technically termed *arrises*, from chipping off or splitting.

Now apply this principle to the skull. The outer softer tough table, which is like wood, is indented and dovetailed; the inner glassy table has its edges simply laid in contact. It is mortifying to see a course of bad reasoning obscure this beautiful subject. They say that the bone growing from its centre, and diverging, shoots its fibres betwixt those which come in an opposite direction; thus making one of the most curious provisions of nature a thing of accident. Is it not enough to ask such reasoners, why there is not a suture on the inside as well as on the out?

The junction of the bones of the head generally being thus exact, and like the most finished piece of cabinet work, let us next inquire, whether there be design or contrivance shown in the manner in which each bone is placed upon another.

Fig 1.



A. The *parietal* bone.
B. The *frontal* bone.
C. The *occipital* bone.
D. The *temporal* bone.
E. The *sphenoid* bone.

When we look upon the side of the skull thus, the temporal suture betwixt the bones A and D is formed in a peculiar manner; the lower, or temporal, bone laps over the superior, or parietal, bone. This, too, has been misunderstood: that is to say, the plan of the building of the bones of the head has not been considered; and this joining, called the squamous* suture, which is a species of scarfing, has been supposed a mere consequence of the pressure of the muscle which moves the jaw.

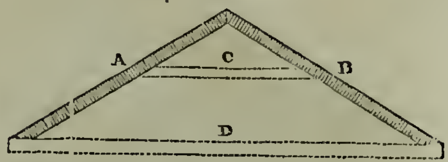
Dr. Monro says, " the manner how I imagine this sort of suture is formed at these places, is, that by the action of the strong temporal muscles on one side, and by the pressure of the brain on the other, the bones are made so thin that they have not large enough surfaces opposed to each other to stop the extension of their fibres in length, and thus to cause the common serrated appearance of sutures; but the narrow edge of the one bone slides over the other.'

The very name of the bones might suggest a better explanation. The *ossa parietalia*† are the two large bones in a regular square, serving as walls to the interior or room of the head, where the brain is lodged.—*See* A *in the foregoing figure.*

Did the reader ever notice how the walls of a house are assisted when thin and overburdened with a roof?

The *wall plate* is a portion of timber built into the wall, to which a transverse or tie-beam is attached by carpentry. This *cogging*, as it is termed, keeps the wall in the perpendicular, and prevents any lateral pressure of the roof.‡ We sometimes see a more clumsy contrivance, a clasp, or a round plate of iron, upon the side of a wall; this has a screw going into the ends of a cross-beam, and by embracing a large portion of the brick-work, it holds the wall from shifting at this point. Or take the instance of a roof supported on inclined rafters, A B:—

Fig. 2.



Were they thus, without further security, placed upon the walls, the weight would tend to spur or press out the walls, which must be strong and heavy to support the roof; therefore, the skeleton of the roof is made into a *truss*, (for so the whole joined carpentry is called.) The upper cross-beam marked by the dotted lines C, is a collar-beam, connecting the rafters of the roof, and stiffening them, and making the weight bear perpendicularly upon the walls. When the transverse beam joins the extremities of the rafters, as indicated by the lower outline D, it is called a *tie-beam*, and is more powerful still in preventing the rafters from pushing out the walls.

Now when a man bears a burden upon his head, the pressure, or horizontal push, comes upon the lower part of the *parietal bones*, and if they had not a tie-beam, they would, in fact, be spurred out, and the bones of the head be crushed down. But the temporal bone D, and still more, the sphenoid bone E, by running across the base of the skull, and having their edges lapping over the lower part of the great walls, or the parietal bones, lock in the walls as if they had iron plates, and answer the purpose of the tie-beam in the roof, or the iron plate in the walls. But the connexion is at the same time so secure, that these bones act equally as a *straining* piece, that is, as a piece of timber, preventing the tendency of the sides *of the skull* to each other.

It may be said, that the skull is not so much like the wall of a house as like the arch of a bridge: let us then consider it in this light.

We have here the two parietal bones, separated and resting against each other, so as to form an arch. In the centering, which is the wooden frame for supporting a stone arch while building, there are some principles that are applicable to the head

* From *squama*, the Latin for a *scale*, the thin edges lying over each other like the scales of a fish.
† From the Latin word *paries*, a wall.
‡ In the second Treatise on Heat, the reader will find an account of the manner in which the expansion of iron by heat, and its subsequent contraction on cooling, is used in order to cog great buildings.

We see that the arch formed by the two parietal bones is not a perfect semi-

Fig. 3.

circle; there is a projection at the centre of each bone, the bone is more convex, and thicker at this part.

The cause assigned for this is, that it is the point from which ossification begins, and where it is, therefore, most perfect. But this is to admit a dangerous principle, that the forms of the bones are matter of chance: and thence we are left without a motive for study, and make no endeavour to comprehend the uses of parts. We find that all the parts which are most exposed to injury are thus strengthened;—the centre of the forehead, the projecting point of the skull behind, and the lateral centres of the parietal and frontal bones. The parts of the head which would strike upon the ground when a man falls, are the strongest, and the projecting arch of the parietal bone is a protection to the weaker temporal bone.

If we compare the skull to the *centering*, where a bridge is to be built over a navigable river, and consequently where the space must be free in the middle, we find that the scientific workmen are careful, by a transverse beam, to protect the points where the principal thrust will be made in carrying up the masonry; this beam does not act as a tie-beam, but as a straining-piece,

Fig. 4.

preventing the arch from being crushed in at this point.

The necessity of strengthening certain points is well exhibited in the carpentry of roofs. In this figure it is clear, that the points A A will receive the pressure of the roof, and if the joining of the puncheons* and rafters be not secure, it will sink down in the form of the dotted line. The workmen would apply braces at these angles to strengthen them.

In the arch, and at the corresponding points of the parietal bones, the object is attained by strengthening these points by increase of their convexity and thickness; and where the workman would support the angles by braces, there are ridges of bone in the calvaria†, or roof of the skull.

If a stone arch fall, it must give way in two places at the same time; the centre cannot sink unless that part of the arch which springs from the pier yields: and in all arches, from the imperfect Roman arch to that built upon modern principles, the aim of the architect is to give security to this point.

In the Roman bridges still entire the arch rises high, with little inclination at the lower part; and in bridges of a more modern date, we see a mass of masonry erected on the pier, sometimes assuming the form of ornament, sometimes of a tower or gateway, but obviously intended at the same time, by the perpendicular load, to resist the horizontal pressure of the arch. If this be omitted in more modern buildings, it is supplied by a finer art, which gives security to the masonry of the pier (to borrow the terms of anatomy), by its internal structure.

In what is termed Gothic Architecture, we see a flying buttress, springing from the outer wall, carried over the roof of the aisle, and abutting against the wall of the upper part, or *clere-story*. From the upright part of this masonry, a pinnacle is raised, which at first appears to be a mere ornament, but which is necessary, by its perpendicular weight, to counteract the horizontal thrust of the arch.

* The puncheons are the upright lateral pieces, the rafters are the timbers which lie oblique, and join the puncheons at A A.

† From the Latin *calva* or *calvaria*, a *helmet*.

Fig. 5.

By all this, we see that if the skull is to be considered as an arch, and the parietal bones as forming that arch, they must be secured at the temporal and sphenoid* bones, the points from which they spring. And, in point of fact, where is it that the skull yields when a man falls, so as to strike the top of his head upon the ground? —in the temples. And yet the joinings are so secure, that the extremity of the bone does not start from its connexions. It must be fractured before it is spurred out, and in that case only does the upper part of the arch yield.

But the best illustration of the form of the head is the dome.

A dome is a vault rising from a circular or elliptical base; and the human skull is, in fact, an elliptical surmounted dome, which latter term means that the dome is higher than the radius of its base. Taking this matter historically, we should presume that the dome was the most difficult piece of architecture, since the first dome erected appears to have been at Rome, in the reign of Augustus—the Pantheon, which is still entire. The dome of St. Sophia, in Constantinople, built in the time of the Emperor Justinian, fell three times during its erection: and the dome of the Cathedral of Florence stood unfinished 120 years for want of an architect. Yet we may, in one sense, say that every builder who tried it, as well as every labourer employed, had the most perfect model in his own head. It is obvious enough, that the weight of the upper part of the dome must disengage the stones from each other which form the lower circle, and tend to break up their joinings, and consequently to press or thrust outwards the circular wall on which it rests. No walls can support the weight, or rather, the lateral thrust, unless each stone of the dome be soldered to another, or the whole hooped together and girded. The dome of St. Paul's has a very strong double iron chain, linked together, at the bottom of the cone; and several other lesser chains between that and the cupola, which may be seen in the section of St. Paul's engraved by Hooker.

The bones of the head are securely bound together, so that the anatomist finds, when every thing is gone, save the bone itself, and there is neither muscle, ligament, nor membrane of any kind, to connect the bones, they are, still, securely joined, and it requires his art to burst them asunder; and for this purpose he must employ a force which shall produce a uniform pressure from the centre outwards; and all the sutures must receive the pressure at one time and equally, or they will not give way. And now is the time to observe another circumstance, which calls for our admiration. So little of accident is there in the joining of the bones, that the edge of a bone at the suture lies over the adjoining bone at one part and under it at another, which, with the dovetailing of the suture, as before described, holds each bone in its place firmly attached; and it is this which gives security to the dome of the cranium.

If we look at the skull in front, we may consider the orbits of the eye as crypts under the greater building. And these under-arches are groined, that is to say, there are strong arched spines of bone, which give strength sufficient to permit the interstices of the groinings, if I may so term them, to be very thin. Betwixt the eye and the brain, the bone is as thin as parchment; but if the

* In the Greek, *sphenoid*—in the Latin, *cuneiform*—like a wedge, because it is wedged among the other bones of the head; but these processes, called wedges, are more like dovetails, which enter into the irregularities of the bones, and hold them locked.

anterior part of the skull had to rest on this, the foundation would be insufficient. This is the purpose of the strong ridge of bone which runs up like a buttress from the temple to the lateral part of the frontal bone, whilst the arch forming the upper part of the orbit is very strong: and these ridges of bone, when the skull is formed with what we call a due regard to security, give an extension to the forehead*.

In concluding this survey of the architecture of the head, let us suppose it so expanded that we could look upon it from within. In looking up to the vault, we should at once perceive the application of the *groin* in masonry; for the groin is that projection in the vault which results from the intersection of two arches running in different directions. One rib or groin extends from the centre of the frontal bone to the most projecting part of the occipital foramen, or opening on the back of the head; the other rib crosses it from side to side of the occipital bone. The point of intersection of these two groins is the thickest and strongest part of the skull, and it is the most exposed, since it is the part of the head which would strike upon the ground when a man falls backwards.

What is termed the base of the skull is strengthened, if we may so express it, on the same principle: it is like a cylinder groin, where the rib of an arch does not terminate upon a buttress or pilaster, but is continued round in the completion of the circle. The base of the skull is irregular, and in many places thin and weak, but these arched spines or ribs give it strength to bear those shocks to which it is of course liable at the joining of the skull with the spine.

Chapter II.

Mechanism of the Spine.

The brain-case is thus a perfect whole, secure on all sides, and strengthened where the exposure to injury is the greatest. We shall see, in the column which sustains it, equal provision for the security of the brain; and, what is most admirable, there is an entirely different principle introduced here; for whereas in the head, the whole aim is firmness in the joinings of the bones, in the spine which supports the head, the object to be attained is mobility or pliancy. In the head, each bone is firmly secured to another; in the spine the bones are not permitted to touch: there is interposed a soft and elastic material, which takes off the jar that would result from the contact of the bones. We shall consider this subject a little more in detail.

The spinal column, as it is called, serves three purposes: it is the great bond of union betwixt all the parts of the skeleton; it forms a tube for the lodgment of the spinal marrow, a part of the nervous system as important to life as the brain itself; and lastly, it is a column to sustain the head.

We now see the importance of the spine, and we shall next explain how the various offices are provided for.

If the protection of the spinal marrow had been the only object of this structure, it is natural to infer that it would have been a strong and unyielding tube of bone; but, as it must yield to the inflexions of the body, it cannot be constituted in so strict an analogy with the skull. It must, therefore, bend; but it must have no abrupt or considerable bending at one part; for the spinal marrow within would in this way suffer.

By this consideration we perceive why there are twenty-four bones in the spine, each bending a little; each articulated or making a joint with its fellow; all yielding in a slight degree, and, consequently, permitting in the whole spine that flexibility necessary to the motions of the body. It is next to be observed that, whilst the spine by this provision moves in every direction, it gains a property which it belongs more to our present purpose to understand. The bones of the spine are called vertebræ; at each interstice between these bones, there is a peculiar gristly substance, which is squeezed out from betwixt the bones, and, therefore, permits them to approach and play a little in the motions of the body. This gristly substance is inclosed in an elastic binding, or membrane of great strength, which passes from the edge or border of one vertebra, to the border of the one next

* Although they are solid arches connected with the building of the cranium, and bear no relation to the surfaces of the brain, the early craniologists would have persuaded us that their forms correspond with the surfaces of the brain, and indicate particular capacities or talents.

it. When a weight is upon the body, the soft gristle is pressed out, and the membrane yields: the moment the weight is removed, the membranes recoil by their elasticity, the gristle is pressed into its place, and the bones resume their position.

We can readily understand how great the influence of these twenty-four joinings must be in giving elasticity to the whole column; and how much this must tend to the protection of the brain. Were it not for this interposition of elastic material, every motion of the body would produce a jar to the delicate texture of the brain, and we should suffer almost as much in alighting on our feet, as in falling on our head. It is, as we have already remarked, necessary to interpose thin plates of lead or slate between the different pieces of a column to prevent the edges (technically called arrises) of the cylinders from coming in contact, as they would, in that case, chip or split off.

But there is another very curious provision for the protection of the brain: we mean the curved form of the spine. If a steel spring, perfectly straight, be pressed betwixt the hands from its extremities, it will resist, notwithstanding its elasticity, and when it does give way, it will be with a jerk.

Such would be the effect on the spine if it stood upright, one bone perpendicular to another; for then the weight would bear equally; the spine would yield neither to one side nor to the other; and, consequently, there would be a resistance from the pressure on all sides being balanced. We, therefore, see the great advantage resulting from the human spine being in the form of an italic *f*. It is prepared to yield in the direction of its curves; the pressure is of necessity more upon one side of the column than on the other; and its elasticity is immediately in operation without a jerk. It yields, recoils, and so forms the most perfect spring; admirably calculated to carry the head without jar, or injury of any kind.

The most unhappy illustration of all this is the condition of old age. The tables of the skull are then consolidated, and the spine is rigid: if an old man should fall with his head upon the carpet, the blow, which would be of no consequence to the elastic frame of a child, may to him prove fatal; and the rigidity of the spine makes every step which he takes vibrate to the interior of the head, and jar on the brain.

We have hinted at a comparison betwixt the attachment of the spine to the pelvis and the insertion of the mast of a ship into the hull. The mast goes directly through the decks without touching them, and the heel of the mast goes into the step, which is formed of large solid pieces of oak timber laid across the keelson. The keelson is an inner keel resting upon the floor-timbers of the ship and directly over the proper keel. These are contrivances for enlarging the base on which the mast rests as a column: for as, in proportion to the height and weight of a column, its base must be enlarged, or it would sink into the earth; so, if the mast were to bear upon a point, it would break through the bottom of the ship.

The mast is supported upright by the shrouds and stays. The shrouds secure it against the lateral or rolling motion, and the stays and backstays against the pitching of the ship. These form what is termed the standing rigging. The mast does not bear upon the deck or on the beams of the ship; indeed there is a space covered with canvas betwixt the deck and the mast.

We often hear of a new ship going to sea to stretch her rigging; that is, to permit the shrouds and stays to be stretched by the motion of the ship, after which they are again braced tight: for if she were overtaken by a storm before this operation, and when the stays and shrouds were relaxed, the mast would lean against the upper deck, by which it would be sprung or carried away. Indeed, the greater proportion of masts that are lost are lost in this manner. There are no boats which keep the sea in such storms as those which navigate the gulf of Finland. Their masts are not attached at all to the hull of the ship, but simply rest upon the step.

Although the spine has not a strict resemblance to the mast, the contrivances of the ship-builder, however different from the provisions of nature, show what object is to be attained; and when we are thus made aware of what is necessary to the security of a column on a moveable base, we are prepared to appreciate the superior provisions of nature for giving security to the human spine.

The human spine rests on what is

called the *pelvis*, or basin;—a circle of bones, of which the haunches are the extreme lateral parts; and the sacrum (which is as the keystone of the arch) may be felt at the lower part of the back. To this central bone of the arch of the pelvis the spine is connected; and, taking the similitude of the mast, the sacrum is as the *step* on which the base of the pillar, like the heel of the mast, is socketed or morticed. The spine is tied to the lateral parts of the pelvis by powerful ligaments, which may be compared to the shrouds. They secure the lower part of the spine against the shock of lateral motion or rolling; but, instead of the stays to limit the play of the spine forwards and backwards in pitching, or to adjust the rake of the mast, there is a very beautiful contrivance in the lower part of the column.

The spine forms here a semicircle which has this effect; that, whether by the exertion of the lower extremities, the spine is to be carried forward upon the pelvis, or whether the body stops suddenly in running, the jar which would necessarily take place at the lower part of the spine A, if it stood upright like a mast, is distributed over several of the bones of the spine, 1, 2, 3, 4, and, therefore, the chance of injury at any particular part is diminished.

Fig. 6.

For example, the sacrum, or centre bone of the pelvis, being carried forward, as when one is about to run, the force is communicated to the lowest bone of the spine. But, then, the surfaces of these bones stand with a very slight degree of obliquity to the line of motion; the shock communicated from the lower to the second bone of the vertebræ is still in a direction very nearly perpendicular to its surface of contact. The same takes place in the communication of force from the second to the third, and from the third to the fourth; so that before the shock of the horizontal motion acts upon the perpendicular spine, it is distributed over four bones of that column, instead of the whole force being concentrated upon the joining of any two, as at A.

If the column stood upright, as indicated at C D, it would be jarred at the lowest point of contact with its base. But by forming a semicircle A B, the motion which in the direction E F, would produce a jar on the very lowest part of the column, is distributed over a considerable portion of the column A B; and in point of fact, this part of the spine never gives way. Indeed, we should be inclined to offer this mode to the consideration of nautical men, as fruitful in hints for improving naval architecture.

Every one who has seen a ship pitching in a heavy sea, must have asked himself why the masts are not upright, or rather, why the foremast stands upright, whilst the main and mizen masts stand oblique to the deck, or, as the phrase is, rake aft or towards the stern of the ship.

The main and mizen masts incline backwards, because the strain is greatest in the forward pitch of the vessel; for the mast having received an impulse forwards, it is suddenly checked as the head of the ship rises; but the mast being set with an inclination backwards, the motion falls more in the perpendicular line from the head to the heel. This advantage is lost in the upright position of the foremast, but it is sacrificed to a superior advantage gained in working the ship; the sails upon this mast act more powerfully in swaying the vessel round, and the perpendicular position causes the ship to tack or stay better; but the perpendicular position, as we have seen, causes the strain in pitching to come at right angles to the mast, and is, therefore, more apt to spring it.

These considerations give an interest

to the fact, that the human spine, from its utmost convexity near its base, inclines backwards.

Chapter III.

Of the Chest.

In extending the parallel which we proposed between the structure of the body and the works of human art, it signifies very little to what part we turn; for the happy adaptation of means to the end will everywhere challenge our admiration, in exact proportion to our success in comprehending the provisions which Supreme Wisdom has made. We turn now to a short view of the bones of the chest.

The thorax, or chest, is composed of bones and cartilages, so disposed as to sustain and protect the most vital parts, the heart and lungs, and to turn and twist with perfect facility in every motion of the body; and to be in incessant motion in the act of respiration, without a moment's interval during a whole life In anatomical description, the thorax is formed of the vertebral column, or spine, on the back part, the ribs on either side, and the breastbone, or sternum, on the fore part. But the thing most to be admired is the manner in which these bones are united, and especially the manner in which the ribs are joined to the breastbone, by the interposition of cartilages, or gristle, of a substance softer than bone, and more elastic and yielding. By this quality they are fitted for protecting the chest against the effects of violence, and even for sustaining life after the muscular power of respiration has become too feeble to continue without this support.

If the ribs were complete circles, formed of bone, and extending from the spine to the breastbone, life would be endangered by any accidental fracture; and even the rubs and jolts to which the human frame is continually exposed, would be too much for their delicate and brittle texture. But these evils are avoided by the interposition of the elastic cartilage. On their forepart the ribs are eked out, and joined to the breastbone by means of cartilages, of a form corresponding to that of the ribs, being, as it were, a completion of the arch of the rib, by a substance more adapted to yield in every shock or motion of the body. The elasticity of this portion subdues those shocks which would occasion the breaking of the ribs. We lean forward, or to one side, and the ribs accommodate themselves, not by a change of form in the bones, but by the bending or elasticity of the cartilages. A severe blow upon the ribs does not break them, because their extremities recoil and yield to the violence. It is only in youth, however, when the human frame is in perfection, that this pliancy and elasticity have full effect. When old age approaches, the cartilages of the ribs become bony. They attach themselves firmly to the breastbone, and the extremities of the ribs are fixed, as if the whole arch were formed of bone unyielding and inelastic. Then every violent blow upon the side is attended with fracture of the rib, an accident seldom occurring in childhood, or in youth.

But there is a purpose still more important to be accomplished by means of the elastic structure of the ribs, as partly formed of cartilage. This is in the action of breathing, or respiration; especially in the more highly-raised respiration which is necessary in great exertions of bodily strength, and in violent exercise. There are two acts of breathing—*expiration*, or the sending forth of the breath; and *inspiration*, or the drawing in of the breath. When the chest is at rest, it is neither in the state of expiration nor in that of inspiration; it is in an intermediate condition between these two acts. And the muscular effort by which either inspiration or expiration is produced, is an act in opposition to the elastic property of the ribs. The property of the ribs is to preserve the breast in the intermediate state between expiration and inspiration. The muscles of respiration are excited alternately, to dilate or to contract the cavity of the chest, and, in doing so, to raise or to depress the ribs. Hence it is, that both in inspiration and in expiration the elasticity of the ribs is called into play; and, were it within our province, it would be easy to show, that the dead power of the cartilages of the ribs preserve life by respiration, after the vital muscular power would, without such assistance, be too weak to continue life.

It will at once be understood, from what has now been explained, how, in

age, violent exercise or exertion is under restraint, in so far as it depends on respiration. The elasticity of the cartilages is gone, the circle of the ribs is now unyielding, and will not allow that high breathing, that sudden and great dilating and contracting of the cavity of the chest, which is required for circulating the blood through the lungs, and relieving the heart amidst the more tumultuous flowing of the blood which exercise and exertion produce.

Chapter IV.

Design shown in the Structure of the Bones and Joints of the Extremities.

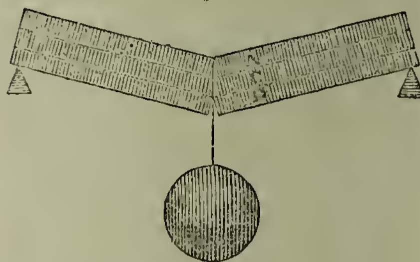
That the bones, which form the interior of animal bodies, should have the most perfect shape, combining strength and lightness, ought not to surprize us, when we find this in the lowest vegetable production.

In the sixteenth century, an unfortunate man who taught medicine, philosophy, and theology, was accused of atheistical opinions, and condemned to have his tongue cut out, and to suffer death. When brought from his cell before the inquisition, he was asked if he believed in God. Picking up a straw which had stuck to his garments, "If," said he, "there was nothing else in nature to teach me the existence of a Deity, even this straw would be sufficient!"

A reed, or a quill, or a bone, may be taken to prove that in Nature's works strength is given with the least possible expense of materials. The long bones of animals are, for the most part, hollow cylinders, filled up with the lightest substance, marrow; and in birds the object is attained by means (if we may be permitted to say so) still more artificial. Every one must have observed, that the breast-bone of a fowl extends along the whole body, and that the body is very large compared with the weight: this is for the purpose of rendering the creature specifically lighter and more buoyant in the air; and that it may have a surface for the attachment of muscles, equal to the exertion of raising it on the wing. This combination of lightness with increase of volume, is gained by air-cells extending through the body, and communicating by tubes between the lungs and cavities of the bones. By these means, the bones, although large and strong to withstand the operation of powerful muscles upon them, are much lighter than those of quadrupeds.

The long bones of the human body, being hollow tubes, are called cylindrical, though they are not accurately so, the reason of which we shall presently explain; and we shall, at the same time, show that their irregularities are not accidental, as some have imagined. But let us first demonstrate the advantage which, in the structure of the bones, is derived from the cylindrical form, or a form approaching to that of the cylinder. If a piece of timber supported on two points, thus—

Fig. 7.

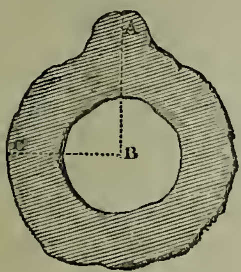


bear a weight upon it, it sustains this weight by different qualities in its different parts. For example, divide it into three equal parts (A,B,C,): the upper part A supports the weight by its solidity and resistance to compression; the lowest part B, on the other hand, resists by its toughness, or adhesive quality. Betwixt the portions acting in so different a manner there is an intermediate neutral, or central part C, that may be taken away without materially weakening the beam, which shows that a hollow cylinder is the form of strength. The Writer lately observed a good demonstration of this:—a large tree was blown down, and lay upon the ground; to the windward, the broken part gaped; it had been torn asunder like the snapping of a rope: to the leeward side of the tree, the fibres of the stem were crushed into one another and splintered; whilst the central part remained entire. This, we presume, must be always the case, more or less; and here we take the opportunity of noticing why the arch is the form of strength. If this transverse piece of timber were in the form of an arch, and supported at the extremities, then its whole thickness, its centre, as well as the upper

and lower parts, would support weight by resisting compression. But the demonstration may be carried much farther to show the form of strength in the bone. If the part of the cylinder which bears the pressure be made more dense, the power of resistance will be much increased; whereas, if a ligamentous covering be added on the other side, it will strengthen the part which resists extension: and we observe a provision of this kind in the tough ligaments which run along the vertebræ of the back.

When we see the bone cut across, we are forced to acknowledge that it is formed on the principle of the cylinder; that is, that the material is removed from the centre, and accumulated on the circumference, thus—

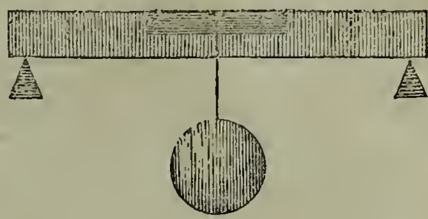
Fig. 8.



We find a spine, or ridge running along the bone, which, when divided by the saw in a transverse direction, exhibits an irregularity, as at A.

The section of this spine shows a surface as dense as ivory, which is, therefore, much more capable of resisting compression than the other part of the cylinder, which is common bone. This declares what the spine is, and the anatomists must be wrong who imagine that the bone is moulded by the action of the muscle, and that the spine is a mere ridge, arising by accident among the muscles. It is, on the contrary, a strengthening of the bone in the direction on which the weight bears. If we resume the experiment with the piece of timber, we shall learn why the spine is harder than the rest of the bone. If a portion of the upper part of the timber be cut away, and a harder wood inserted in its place, the beam will acquire a new power of resisting fracture, because, as we have stated, this part of the wood does not yield but by being crushed, and the in-

Fig. 9.



sertion of the harder portion of wood increases this property of resistance. With this fact before us we may return to the examination of the spine of bone. We see that it is calculated to resist pressure, first, because it is farther removed from the centre of the cylinder; and, secondly, because it is denser, to resist compression, than the other part of the circumference of the bone*.

This explanation of the use of a spine upon a bone gives a new interest to osteology †. The anatomist ought to deduce from the form of the spine the motions of the limb; the forces bearing upon the bone, and the nature and the common place of fracture: while, to the general enquirer an agreeable process of reasoning is introduced in that department, which is altogether without interest when the "*irregularities*" of the bone are spoken of, as if they were the accidental consequences of the pressure of the flesh upon it.

Although treating of the purely mechanicle principle, it is, perhaps, not far removed from our proper object to remark, that a person of feeble texture and indolent habits has the bone smooth, thin, and light; but that Nature, solicitous for our safety, in a manner which we could not anticipate, combines with the powerful muscular frame a dense and perfect texture of bone, where every spine and tubercle is completely developed. And thus the inert and mechanical provisions of the bone always bear relation to the muscular power of the limb, and exercise is as necessary to the perfect constitution of a bone as it is to the perfection of the muscular power. Jockies speak correctly enough, when they use the term "*blood and*

* As the line A B extends farther from the centre than B C, on the principle of a lever, the resistance to transverse fracture will be greater in the direction A B than B C.

† *Osteology*, from the Greek words, signifying discourse on bone, being the demonstration of the forms and connexion of the different bones.

bone," as distinguishing the breed or genealogy of horses; for blood is an allowable term for the race, and bone is so far significant, that the bone of a running horse is remarkably compact compared with the bone of a draught horse. The reader can easily understand, that the span in the gallop must give a shock in proportion to its length; and, as in man, so in the horse, the greater the muscular power the denser and stronger is the bone.

The bone not being as a mere pillar, intended to bear a perpendicular weight, we ought not to expect uniformity in its shape. Each bone, according to its place, bears up against the varying forces that are applied to it. Consider two men wrestling together, and then think how various the property of resistances must be: here they are pulling, and the bones are like ropes; or again, they are writhing and twisting, and the bones bear a force like the axle-tree between two wheels; or they are like a pillar under a great weight; or they are acting as a lever.

To withstand these different shocks, a bone consists of three parts, the *earth* of bone (sub-phosphate of lime); *fibres* to give it toughness; and *cartilage* to give it elasticity. These ingredients are not uniformly mixed up in all bones; but some bones are hard, from the prevalence of the earth of bone; some more fibrous, to resist a pull upon them; and some more elastic, to resist the shocks in walking, leaping, &c. But to return to the forms:—Whilst the centre of the long bones is, as we have stated, cylindrical, their extremities are expanded, and assume various shapes. The expansion of the head of the bone is to give a greater, and consequently a more secure surface for the joint, and its form regulates the direction in which the joint is to move. A jockey, putting his hand on the knee of a colt, and finding it broad and flat, augurs the perfection of the full-grown horse. To admit of this enlargement and difference of form, a change in the internal structure of the bone is necessary, and the hollow of the tube is filled up with *cancelli*, or lattice-work. These *cancelli* of the bone are minute and delicate-like wires, which form lattice-work, extending in all directions through the interior of the bone, and which, were it elastic, would be like a sponge.—This more uniform texture of the bone permits the outer shell to be very thin, so that whilst the centre of the long bones are cylinders, their extremities are of a uniform cancellated structure. But it is pertinent to our purpose to notice, that this minute lattice-work, or the cancelli which constitute the interior structure of bone, have still reference to the forces acting on the bone; if any one doubts this, let him make a section of the upper and lower end of the thigh-bone, and let him inquire what is the meaning of the difference in the *lie* of these minute bony fibres, in the two extremities? He will find that the head of the thigh bone stands obliquely off from the shaft, and that the whole weight bears on what is termed the *inner trochanter;* and to that point, as to a buttress, all these delicate fibres converge, or point from the head and neck of the bone, which may be rudely represented in this way.

Fig. 10.

The head of the thigh-bone, to show the direction of the *cancelli*, converging to the line of gravity.

We may here notice an opinion that has been entertained, in regard to the size of animals. It is believed that the material of bone is not capable of supporting a creature larger than the elephant, or the *mastodon*, which is the name of an extinct animal of great size, the osseous remains of which are still found. This opinion is countenanced by observing that their bones are very clumsy, that their spines are of great thickness, and that their hollow cylinders are almost filled up with bone.

It may be illustrated in this manner;—A soft stone projecting from a wall may make a stile, strong enough to bear a person's weight; but if it were neces-

sary to double its length, the thickness must be more than doubled, or a freestone substituted; and were it necessary to make this freestone project twice as far from the wall, even if doubled in thickness, it would not be strong enough to bear a proportioned increase of weight: granite must be placed in its stead; and even the granite would not be capable of sustaining four times the weight which the soft stone bore in the first instance. In the same way the stones which form an arch of a large span must be of the hardest granite, or their own weight would crush them. The same principle is applicable to the bones of animals. The material of bone is too soft to admit an indefinite increase of weight; and it is another illustration of what was before stated, that there is a relation established through all nature, and that the very animals which move upon the surface of the earth are proportioned *to its magnitude*, and the gravitation to its centre. Archdeacon Paley has with great propriety taken the instance of the form of the ends of bones, as proving design in the mechanism of a joint. But there is something so highly interesting in the conformation of the whole skeleton of an animal, and the adaptation of any one part to all the other parts, that we must not let our readers remain ignorant of the facts, or of the important conclusions drawn from them.

What we have to state has been the result of the studies of many naturalists; but although they have laboured, as it were, in their own department of comparative anatomy, they have failed to seize upon it with the privilege of genius, and to handle it in the masterly manner of Cuvier.

Suppose a man ignorant of anatomy to pick up a bone in an unexplored country, he learns nothing, except that some animal has lived and died there; but the anatomist can, by that single bone, estimate, not merely the size of the animal, as well as if he saw the print of its foot, but the form and joints of the skeleton, the structure of its jaws and teeth, the nature of its food, and its internal economy. This, to one ignorant of the subject, must appear wonderful, but it is after this manner that the anatomist proceeds: let us suppose that he has taken up that portion of bone in the limb of the quadruped which corresponds to the human wrist; and that he finds that the form of the bone does not admit of free motion in various directions, like the paw of the carnivorous creature. It is obvious, by the structure of the part, that the limb must have been merely for supporting the animal, and for progression, and not for seizing prey. This leads him to the fact that there were no bones resembling those of the hand and fingers, or those of the claws of the tiger; for the motions which that conformation of bones permits in the paw, would be useless, without the rotation of the wrist—he concludes that these bones were formed in one mass, like the cannon bone, pastern-bone, and coffin-bones of the horse's foot.*

The motion limited to flection and extension of the foot of a hoofed animal implies the absence of a collar bone and a restrained motion in the shoulder joint; and thus the naturalist, from the specimen in his hand, has got a perfect notion of all the bones of the anterior extremity! The motions of the extremities imply a condition of the spine which unites them. Each bone of the spine will have that form which permits the bounding of the stag, or the galloping of the horse, but it will not have that form of joining which admits the turning or writhing of the spine, as in the leopard or the tiger.

And now he comes to the head:—the teeth of a carnivorous animal, he says, would be useless to rend prey, unless there were claws to hold it, and a mobility of the extremities like the hand, to grasp it. He considers, therefore, that the teeth must have been for bruising herbs, and the back teeth for grinding. The socketing of these teeth in the jaw gives a peculiar form to these bones, and the muscles which move them are also peculiar; in short, he forms a conception of the shape of the skull. From this point he may set out anew, for by the form of the teeth, he ascertains the nature of the stomach, the length of the intestines, and all the peculiarities which mark a vegetable feeder

Thus the whole parts of the animal system are so connected with one another, that from one single bone or frag-

* For these are solid bones, where it is difficult to recognise any resemblance to the carpus, metacarpus and bones of the fingers; and yet comparative anatomy proves that these moveable bones are of the same class with those in the solid hoof of the *belluæ* of Linnæus.

ment of bone, be it of the jaw, or of the spine, or of the extremity, a really accurate conception of the shape, motions, and habits of the animal, may be formed.

It will readily be understood that the same process of reasoning will ascertain, from a small portion of a skeleton, the existence of a carnivorous animal, or of a fowl, or of a bat, or of a lizard, or of a fish; and what a conviction is here brought home to us, of the extent of that plan which adapts the members of every creature to its proper office, and yet exhibits a system extending through the whole range of animated beings, whose motions are conducted by the operation of muscles and bones

After all, this is but a part of the wonders disclosed through the knowledge of a thing so despised as a fragment of bone. It carries us into another science; since the knowledge of the skeleton not only teaches us the classification of creatures, now alive, but affords proofs of the former existence of animated beings which are not now to be found on the surface of the earth. We are thus led to an unexpected conclusion from such premises: not merely the existence of an individual animal, or race of animals; but even the changes which the globe itself has undergone in times before all existing records, and before the creation of human beings to inhabit the earth, are opened to our contemplation.

Of Standing

This may appear to some a very simple inquiry, and yet it is very ignorant to suppose that it is so. The subject has been introduced in this fashion:—"Observe these men engaged in raising a statue to its pedestal with the contrivances of pullies and levers, and how they have placed it on the pedestal and are soldering it to keep it steady, lest the wind should blow it down. This statue has the fair and perfect proportions of the human body; to all outward appearance it ought to stand."

In the following passage, we have the same idea thrown out in a manner which we are apt to call *French.* Were a man cast on a desert shore, and there to find a beautiful statue of marble, he would naturally exclaim,—"Without doubt, there have been inhabitants here: I recognise the hand of a famous sculptor: I admire the delicacy with which he has proportioned all the members of the body to give them beauty, grace, and majesty, to indicate the motion and expression of life." But it may be asked, what would such a man think if his companion were to say,—"Not at all, no sculptor made this statue; it is formed, to be sure, in the best taste, and according to the rules of art, but it is formed by chance: amongst the many fragments of marble, there has been one thus formed of itself. The rain and the winds have detached it from the mountain, and a storm has placed it upright on the pedestal. The pedestal, too, was prepared of itself in this lonely place. True, it is like the Apollo, or the Venus, or the Hercules. You might believe that the figure lived and thought; that it was prepared to move and speak; but it owes nothing to art; blind chance has placed it there."*

The first passage suggests the conviction that the power of standing proceeds not from any symmetry, as in a pillar, or from gravitation alone. It, in fact, proceeds from an internal provision, by which a man is capable of estimating, with great precision, the inclination of his body, and correcting the bias by the adjustment of the muscles. In the second passage, it is meant to be shown, that the outward proportion of the form bears a relation to the internal structure; that grace and expression are not superficial qualities, and that only the Divine Architect could form such a combination of animated machinery.

We shall consider how the human body is prepared by mechanical contrivances to stand upright, and by what fine sense of the gravitation of the body the muscles are excited to stiffen the otherwise loose joints, and to poise the body on its base.

Of the Foot.

Let us take the arrangement of the bones of the foot, according to the demonstration of the anatomists.

They are divided into the *tarsus,* which is composed of seven bones, reaching from the heel to the middle of the foot. The *metatarsus,* which con-

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* *Démonstration de l'Existence de Dieu, par Fenelon.*

sists of five long bones laid parallel to each other, and extending from the *tarsus* to the roots of the toes. The bones of the toes are called *phalanges*, from being in the form of a *phalanx*.

There are in all thirty-six bones in the foot; and the first question that naturally arises, is, why should there be so many bones? The answer is, In order that there may be so many joints; for the structure of a joint not only permits motion, but bestows elasticity.

A joint then consists of the union of two bones, of such a form as to permit the necessary motion: but they are not in contact: each articulating surface is covered with cartilage, to prevent the jar which would result from the contact of the bones. This cartilage is elastic, and the celebrated Dr. Hunter discovered that the elasticity was in consequence of a number of filaments closely compacted, and extending from the surface of the bone, so that each filament is perpendicular to the pressure made upon it. The surface of the articulating cartilage is perfectly smooth, and is lubricated by a fluid called *synovia*, signifying a mucilage, a viscous or thick liquor. This is vulgarly called *joint oil*, but it has no property of oil, although it is better calculated than any oil to lubricate the interior of the joint.

When inflammation comes upon a joint, this fluid is not supplied, and the joint is stiff, and the surfaces creak upon one another like a hinge without oil. A delicate membrane extends from bone to bone, confining this lubricating fluid, and forming the boundary of what is termed the cavity of the joint, although, in fact, there is no unoccupied space. External to this capsule* of the joint, there are strong ligaments going from point to point of the bones, and so ordered as to bind them together without preventing their proper motions. From this description of a single joint, we can easily conceive what a spring or elasticity is given to the foot, where thirty-six bones are jointed together.

An elegant author has this very natural remark on the joints:—" In considering the joints, there is nothing, perhaps, which ought to move our gratitude more than the reflection, *how well they wear*. A limb shall swing upon its hinge, or play in its socket many hundred times in an hour, for sixty years together, without diminution of its agility, which is a long time for anything to last, for anything so much worked and exercised as the joints are. This durability I should attribute, in part, to the provision which is made for the preventing of wear and tear: first, by the polish of cartilaginous surfaces; secondly, by the healing lubrication of the mucilage; and, in part, to that astonishing property of animal constitutions, assimilation, by which, in every portion of the body, let it consist of what it will, substance is restored and waste repaired."—*Paley*.

If the ingenious author's mind had been professionally called to contemplate this subject, he would have found another explanation. There is no resemblance betwixt the provisions against the wear and tear of machinery and those for the preservation of a living part. As the structure of the parts is originally perfected by the action of the vessels, the function or operation of the part is made the stimulus to those vessels. The cuticle on the hands wears away like a glove; but the pressure stimulates the living surface to force successive layers of skin under that which is wearing, or, as the Anatomists call it, disquamating; by which they mean, that the cuticle does not change at once, but comes off in *squamæ*, or scales. The teeth are subject to pressure in chewing or masticating, and they would, by this action, have been driven deeper in the jaw, and rendered useless, had there not been a provision against this mechanical effect. This provision is a disposition to grow, or rather to shoot out of their sockets; and this disposition to project, balances the pressure which they sustain; and when one tooth is lost, its opposite rises, and is in danger of being lost also, for want of that very opposition.

The most obvious proof of contrivance is the junction of the foot to the bones of the leg at the ankle joint. The two bones of the leg, called the *tibia* and the *fibula*, receive the great articulating bone of the foot (the *astragalus*) betwixt them. And the extremities of these bones of the leg project so as to form the outer and inner ankle. Now, when we step forward, and whilst the foot is raised, it rolls easily upon the ends of these bones, so that the toe

* From *capsula*, a little case, or box.

may be directed according to the inequalities of the ground we are to tread upon; but when the foot is planted, and the body is carried forward perpendicularly over the foot, the joint of the leg and foot becomes fixed, and we have a steady base to rest upon. We next observe, that, in walking, the heel first touches the ground. If the bones of the leg were perpendicular over the part which first touches the ground, we should come down with a sudden jolt, instead of which we descend in a semicircle, the centre of which is the point of the heel.

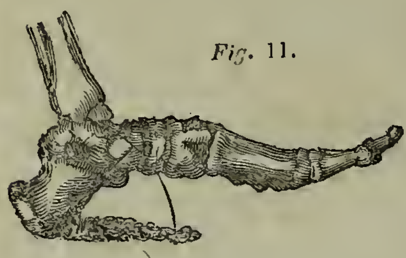


Fig. 11.

And when the toes have come to the ground we are far from losing the advantages of the structure of the foot, since we stand upon an elastic arch, the hinder extremity of which is the heel, and the anterior the balls of the toes. A finely formed foot should be high in the instep. The walk of opera dancers is neither natural nor beautiful; but the surprising exercises which they perform give to the joints of the foot a freedom of motion almost like that of the hand. We have seen the dancers, in their morning exercises, stand for twenty minutes on the extremities of their toes, after which the effort is to bend the inner ankle down to the floor, in preparation for the Bolero step. By such unnatural postures and exercises the foot is made unfit for walking, as may be observed in any of the retired dancers and old *figurantes*. By standing so much upon the toes, the human foot is converted to something more resembling that of a quadruped, where the heel never reaches the ground, and where the paw is nothing more than the phalanges of the toes.

This arch of the foot, from the heel to the toe, has the astragalus (A) resembling the keystone of an arch; but, instead of being fixed, as in masonry, it plays freely betwixt two bones, and from these two bones, B and C, a strong

Fig. 12.

elastic ligament is extended, on which the bone (A) rests, sinking or rising as the weight of the body bears upon it, or is taken off, and this it is enabled to do by the action of the ligament which runs under it.

This is the same elastic ligament which runs extensively along the back of the horse's hind leg and foot, and gives the fine spring to it, but which is sometimes ruptured by the exertion of the animal in a leap, producing irrecoverable lameness.

Having understood that the arch of the foot is perfect from the heel to the toe, we have next to observe, that there is an arch from side to side; for when a transverse section is made of the bones of the foot, the exposed surface presents a perfect arch of wedges, regularly formed like the stones of an arch in masonry. If we look down upon the bones of the foot, we shall see that they form a complete circle horizontally, leaving a space in their centre. These bones thus form three different arches—forward; across; and horizontally: they are wedged together, and bound by ligaments, and this is what we alluded to when we said that the foundations of the Eddystone were not laid on a better principle; but our admiration is more excited in observing, that the bones of the foot are not only wedged together, like the courses of stone for resistance, but that solidity is combined with elasticity and lightness.

Notwithstanding the mobility of the foot in some positions, yet when the weight of the body bears directly over it, it becomes immoveable, and the bones of the leg must be fractured before the foot yields.

We shall proceed to explain how the knee-joint and hip-joint, independently of the exertion of muscles, become firm in the standing position, and when at rest: but, before we enter upon this, let us understand the much talked-of demonstration of Borelli, who explained the manner in which a bird sits upon a branch when asleep. The weight of

the creature, and the consequent flexion of the limbs drawing the tendons of the talons, so as to make them grasp the branch without muscular effort.

Fig. 13.

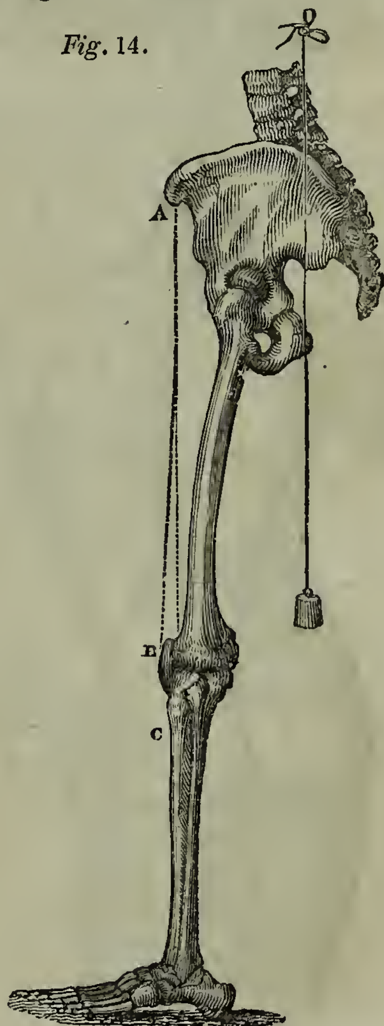
The muscle A passing over the joint at B, and then proceeding to the back of the leg, and behind the joint at C, and so descending behind the foot at D, it extends to the talons; and the weight of the bird, bending the joint B and C, produces the effect of muscular effort, and makes the claws cling.

But why should the anatomist have recourse to this piece of comparative anatomy, when he has so fine an example in the human body? And one which is much more interesting, as, in fact, it is the foundation of reasoning upon the diseases and accidents of the limb. If this beautiful arrangement in the healthy and perfect structure of a man's limb be not attended to, it would be easy to prove that many important circumstances, in regard to disease and accidents, must remain obscure.

The posture of a soldier under arms, when his heels are close together, and his knees straight, is a condition of painful restraint. Observe, then, the change in the body and limbs, when he is ordered to stand at ease; the firelock falls against his relaxed arms, the right knee is thrown out, and the tension of the ankle joint of the same leg is relieved, whilst he loses an inch and a half of his height, and sinks down upon his left hip. This command to "stand at ease," has a higher authority than the general orders. It is a natural relaxation of all the muscles; which are, consequently, relieved from a painful state of exertion: and the weight of the body bears so upon the lower extremity, as to support the joints independently of muscular effort. The advantage of this will be understood, when we consider that all muscular effort is made at the expense of a living power, which, if excessive, will exhaust and weary a man, whilst the position of rest which we are describing is without effort, and therefore gives perfect relief. And it is this which makes boys and girls, who are out of health and languid, lounge too much in the position of relief, from whence comes permanent distortion.

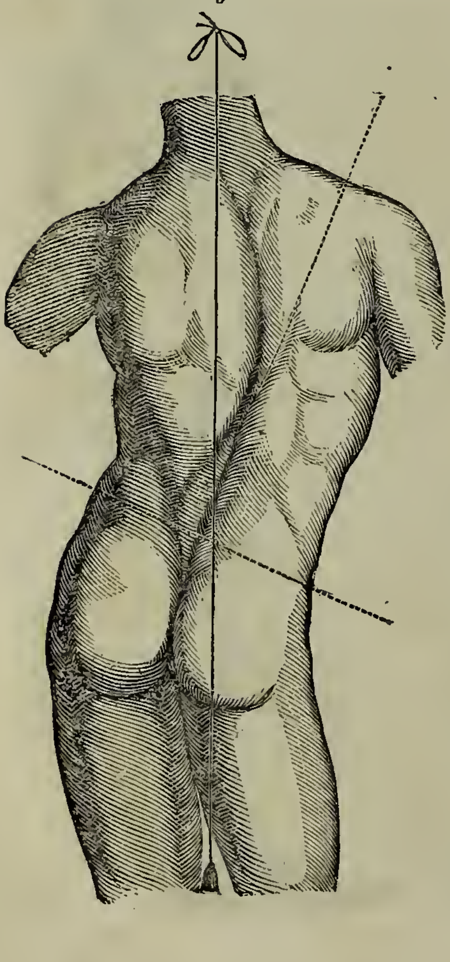
This figure represents the bones of the leg.

Fig. 14.



The plumb-line shows the direction of the gravitation of the body falling behind the head of the thighbone. Now, if it be understood that the motions of the trunk are performed on the centre of the head of the thighbone; it must follow that the weight of the body in the direction of the plumb-line must raise the coner of the haunch-bone, at A. From this corner of the bone, a broad and strong band runs down to the knee-pan, B, in the direction of the dotted line. The powerful muscles which extend the leg are attached to the knee-pan, and through the ligament at C, operate on the bones of the leg, stretching them, and preventing the flexion of the joint; but, in the absence of the activity of these muscles, the band reaching from A to B, drawn, as we have said, by the weight of the body, is equivalent to the exertion of the muscles, braces the knee-joint, and extends the leg; and we have before

Fig. 15.



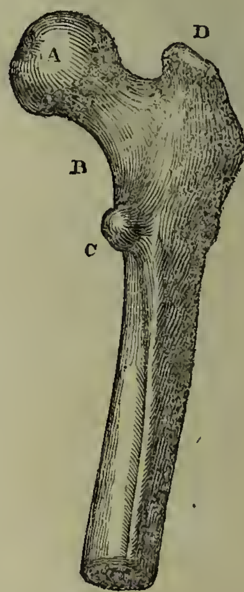
seen that the extension of the leg fixes the ankle-joint. Thus the limb is made a firm pillar under the weight of the body, without muscular effort.

When the human figure is left to its natural attitudes, we see a variety and contrast in the position of the trunk and limbs.

This position of the body resting on the lower extremities throws the trunk into an elegant line, and places the limbs in beautiful contrast, as we see in all the best specimens of sculpture. *See fig.* 15.

Now that we have understood that the lower extremity becomes in some positions a firm pillar, it is the more necessary to observe the particular form of the head of the thigh bone, (*fig.* 16.)

Fig. 16.



It is here seen that the head of the bone A stands off from the shaft by the whole length of the neck of the bone B; the effect of this is, that as the powerful muscles are attached to the knobs of bone C D, they turn the thigh-bone round in walking with much greater power than if the head of the bone were on a line with the shaft. They, in fact, acquire a lever power, by the distance of D from A, as, during the action of these muscles, the limb is stiff, the rolling of the thigh directs the toe outwards in walking.

When the weight of the body is perpendicularly over the ball of the great toe, the whole body is twisted round on that point as on a pivot. This rolling

of the body on the ball of the toe, and consequent turning out of the toes in stepping forward, is necessary to the freedom and elasticity of the motion. The form of all the bones of the leg, and the direction of all the muscles of the thigh and leg, combine to this effect. So far is it from being true, as painters affect to say, that the turning out of the toes is the result of the lessons of the dancing-master.

A certain squareness in the position of the feet is consistent with strength, as we sec in the statues of the Hercules, &c.; but the lightness of a Mercury is indicated by the direction of the toes outwards. In women, there would be a defect from the breadth of the pelvis, and a rolling and an awkward gait would be the consequence; but in them the foot is more turned out, and a light, elastic step balances the defect arising from the form of the pelvis. Any one may be convinced of this by observing people who walk awkwardly, especially if they walk unequally. Look at their feet, and you will see that one foot goes straight forward, whilst the other is turned outwards, and that when they come upon the straight foot, they come down awkwardly, and have no spring from it.

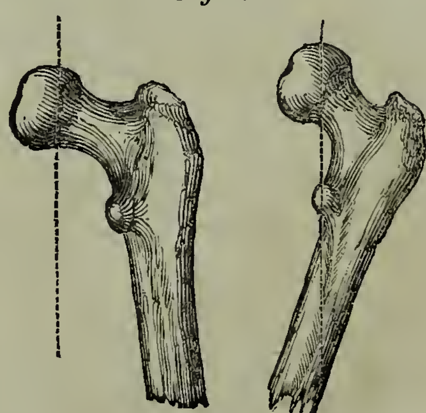
There is another curious circumstance in the form of the thighbone, showing how it is calculated for strength as well as freedom of motion. To understand it, we must first look to the *dishing* of a wheel—the dishing is the oblique position of the spokes from the nave to the felly, giving the wheel a slightly conical form. When a cart is in the middle of a road, the load bears equally upon both wheels, and both wheels stand with their spokes oblique to the line of gravitation.

If the cart is moving on the side of a barrel-shaped road, or if one wheel falls into a rut, the whole weight comes upon one wheel: but the spokes of that wheel, which were oblique to the load when it supported only one half of the weight, are now perpendicular under the pressure, and are capable of sustaining the whole. If roads were made perfectly level, and had no holes in them, the wheels of carts might be made without dishing; but if a cart is calculated for a country road, let the wheelwright consider what equivalent he has to give for that very pretty result proceeding from the obliquity of the spokes, or *dishing* of the wheel.

Fig. 17.

When we return to consider the human thighbone, we see that the same principle holds; that is to say, that whilst a man stands on both his legs, the necks of the thigh bones are oblique to the line of gravitation of the body; but when one foot is raised, the whole body then being balanced on one foot, a change takes place in the position of the thighbone, and the obliquity of that bone is diminished; or, in other words, now that it has the whole weight to sustain, it is perpendicular under it, and has therefore acquired greater strength. See *Fig.* 18.

Fig. 18.



Chapter V.

Of the Tendons compared with Cordage.

Where nature has provided a perfect system of columns, and levers, and pullies, we may anticipate that the cords by which the force of the muscles is concentrated on the moveable bones, must be constructed with as curious a provision for their offices. In this surmise we shall not be disappointed.

To understand what is necessary to the strength of a rope or cable, we must learn what has been the object of the improvements and patents in this manufacture. The first process in rope-making, is hatchelling the hemp; that is, combing out the short fibres, and placing the long ones parallel to one another. The second is, spinning the hemp into yarns. And here the principle must be attended to, which goes through the whole process in forming a cable; which is that the fibres of the hemp shall bear an equal strain: and the difficulty may be easily conceived, since the twisting must derange the parallel position of the fibres. Each fibre, as it is twisted, ties the other fibres together, so as to form a continued line, and it bears at the same time, a certain portion of the strain, and so each fibre alternately. The third step of the process is making the yarns. Warping the yarns, is stretching them to a certain length; and for the same reason, that so much attention has been paid to the arrangement of the fibres for the yarns, the same care is taken in the management of the yarns for the strands. The fourth step of the process is to form the strands into ropes. The difficulty of the art has been to make them bear alike, especially in great cables, and this has been the object of patent machinery. The *hardening*, by twisting, is also an essential part of the process of rope-making; for without this, it would be little better than extended parallel fibres of hemp. In this twisting, first of the yarns, and then of the strands, those which are on the outer surface must be more stretched than those near the centre; consequently, when there is a strain upon the rope, the outer fibres will break first, and the others in succession. It is to avoid this, that each yarn and each strand, as it is twisted or hardened, shall be itself revolving, so that when drawn into the cable, the whole component parts may, as nearly as possible, resist the strain in an equal degree; but the process is not perfect, and this we must conclude from observing how different the construction of a tendon is from that of a rope. A tendon consists of a strong cord, apparently fibrous; but which, by the art of the anatomist, may be separated into lesser cords, and these, by maceration, can be shown to consist of cellular membrane, the common tissue that gives firmness to all the textures of the animal body. The peculiarity here results merely from its remarkable condensation. But the cords of which the larger tendon consists, do not lie parallel to each other, nor are they simply twisted like the strands of a rope; they are, on the contrary, plaited or interwoven together.

If the strong tendon of the heel, or Achilles tendon, be taken as an example, on first inspection, it appears to consist of parallel fibres, but by maceration, these fibres are found to be a web of twisted cellular texture. If you take your handkerchief, and, slightly twisting it, draw it out like a rope, it will seem to consist of parallel cords; such is, in fact, so far the structure of a tendon. But, as we have stated, there is something more admirable than this, for the tendon consists of subdivisions, which are like the strands of a rope; but instead of being twisted simply as by the process of hardening, they are plaited or interwoven in a way that could not be imitated in cordage by the turning of a wheel. Here then is the difference,—by the twisting of a rope, the strands cannot resist the strain equally, whilst we see that this is provided for in the tendon by the regular interweaving of the yarn, if we may so express it, so that every fibre deviates from the parallel line in the same degree, and, consequently, receives the same strain when the tendon is pulled. If we seek for examples illustrative of this structure of the tendons, we must turn to the subject of ship-rigging, and see there how the seaman contrives, by undoing the strands and yarns of a rope, and twisting them anew, to make his splicing stronger than the original cordage. A sailor opens the ends of two ropes thus:*

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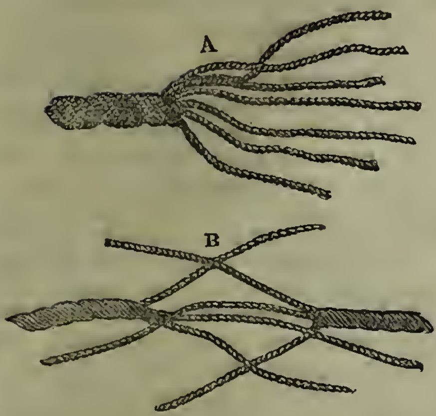
* A, Strands and Yarns opened.
B, Ends opened and laid for splicing, in a manner exactly like the interlacing of the tendon.

Fig. 19.



and places the strand of one opposite and between the strand of another, and so interlaces them. And this explains why a hawser-rope, a sort of small cable, is spun of *three* strands; for as they are necessary for many operations in the rigging of a ship, they must be formed in a way that admits of being cut and spliced, for the separation of three strands, at least, is necessary for knotting, splicing, whipping, mailing, &c., which are a few of the many curious contrivances for joining the ends of ropes, and for strengthening them by filling up the interstices to preserve them from being cut or frayed. As these methods of splicing and plaiting in the subdivisions of the rope make an intertexture stronger than the original rope, it is an additional demonstration, if any were wanted, to show the perfection of the cordage of an animal machine, since the tendons are so interwoven; and until the yarns of one strand be separated and interwoven with the yarns of another strand, and this done with regular exchange, the most approved patent ropes must be inferior to the corresponding part of the animal machinery.

A piece of cord of a new patent has been shown to us, which is said to be many times stronger than any other cord of the same diameter. It is so far upon the principle here stated, that the strands are plaited instead of being twisted; but the tendon has still its superiority, for the lesser yarns of each strand in it are interwoven with those of other strands. It, however, gratifies us to see, that the principle we draw from the animal body is here confirmed. It may be asked, do not the tendons of the human body sometimes break? They do; but in circumstances which only add to the interest of the subject. By the exercise of the tendons, (and their exercise is the act of being pulled upon by the muscles, or having a strain made on them,) they become firmer and stronger; but in the failure of muscular activity, they become less capable of resisting the tug made upon them, and if, after a long confinement, a man has some powerful excitement to muscular exertion, then the tendon breaks. An old gentleman, whose habits have been long staid and sedentary, and who is very guarded in his walk, is upon an annual festival tempted to join the young people in a dance; then he breaks his tendo Achillis. Or a sick person, long confined to bed, is, on rising, subject to a rupture or hernia, because the tendinous expansions guarding against protrusion of the internal parts, have become weak from disuse.

Such circumstances remind us that we are speaking of a living body, and that, in estimating the properties of the machinery, we ought not to forget the influence of life, and that the natural exercise of the parts, whether they be active or passive, is the stimulus to the circulation through them, and to their growth and perfection.

Chapter VI.

Of the Muscles—of Muscularity and Elasticity.

There are two powers of contraction in the animal frame—elasticity, which is common to living and dead matter, and the muscular power, which is a property of the living fibre.

The muscles are the only organs which properly have the power of contraction, for elasticity is never exerted but in consequence of some other power bending or stretching the elastic body. In the muscles, on the contrary, motion originates; there being no connexion, on mechanical principles, betwixt the exciting cause and the power brought into action.

The real power is in the muscles, while the safeguard against the excess of that power is in the elasticity of the parts. This is obvious in the limbs and general texture of the frame; but it is most perfectly exhibited in the organs

of circulation. If the action of the heart impelled the blood against parts of solid texture, they would quickly yield. When, by accident, this does take place, even the solid bone is very soon destroyed. But the coats of the artery which receive the rush of blood from the heart, although thin, are limber and elastic; and by this elasticity or yielding they take off or subdue the shock of the heart's action, while no force is lost; for as the elastic artery has yielded to the sudden impulse of the heart, it contracts by elasticity in the interval of the heart's pulsation; and the blood continues to be propelled onward in the course of the circulation, without interval, though regularly accelerated by the pulse of the heart.

If a steam-engine were used to force water along the water-pipes, without the intervention of some elastic body, the water would not flow continuously, but in jerks, and, therefore, a reservoir is constructed containing air, into which the water is forced, against the elasticity of the air. Thus, each stroke of the piston is not perceptibly communicated to the conduit-pipe, because the intervals are supplied by the push of the compressed air. The office of the reservoir containing air is performed in the animal body by the elasticity of the coats of the arteries, by which means the blood which flows interruptedly into the arteries has a continuous and uninterrupted flow in the veins beyond them.

A muscle is fibrous, that is, it consists of minute threads bundled together, the extremities of which are connected with the tendons which have been described. Innumerable fibres are thus joined together to form one muscle, and every muscle is a distinct organ. Of these distinct muscles for the motions of the body there are not less than 436 in the human frame, independent of those which perform the internal vital motions. The contractile power, which is in the living muscular fibre, presents appearances which, though familiar, are really the most surprising of all the properties of life. Many attempts have been made to explain this property, sometimes by chemical experiment, sometimes on mechanical principles, but always in a manner repugnant to common sense. We must be satisfied with saying, that it is an endowment, the cause of which it would be as vain to investigate as to resume the search into the cause of gravitation.

The ignorance of the cause of muscular contraction does not prevent us from studying the laws which regulate it, and under this head are included subjects of the highest interest; which, however, we must leave, to pursue the mechanical arrangement of the muscles.

Since we have seen that there are 436 distinct muscles in the body, it is due to our readers to explain how they are associated to effect that combination which is necessary to the motion of the limbs and to our perfect enjoyment. In the first place, the million of fibres, which constitute a single muscle, are connected by a tissue of nerves, which produce a union or sympathy amongst them, so that one impulse causes a simultaneous effort of all the fibres attached to the same tendon. When we have understood that the muscles are distinct organs of motion, we perceive that they must be classed and associated in order that many shall combine in one act; and that others, their opponents, shall be put in a state to relax, and offer no opposition to those which are active. These relations can only be established through *nerves*, which are the organs of communication with the brain, or sensorium. The nerves convey the will to the muscles, and at the same time they class and arrange them so as to make them consent to the motions of the body and limbs.

On first looking to the manner in which the muscles are fixed into the bones, and the course of their tendons, we observe everywhere the appearance of a sacrifice of mechanical power, the tendon being inserted into the bone in such a manner as to lose the advantage of the lever. This appears to be an imperfection, until we learn that there is an accumulation of vital power in the muscle in order to attain velocity of movement in the member, (*fig.* 20.)

The muscle D, which bends the fore-arm, is inserted into the radius E, so near the fulcrum, or centre of motion in the elbow joint, and so oblique that it must raise the hand and fore-arm with disadvantage. But, correctly speaking, the power of the muscle is not sacrificed, since it gains more than an equivalent in the rapid and lively motions of the hand and fingers, and since these rapid motions are necessary to us in a thousand familiar actions;

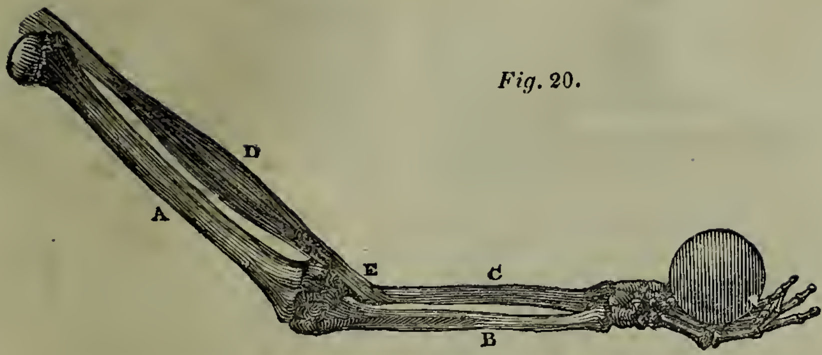


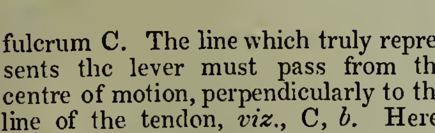
Fig. 20.

and to attain this, the Creator has given sufficient vital power to the muscles to admit of the sacrifice of the mechanical or lever power, and so to provide for every degree and variety of motion which may answer to the capacities of the mind.

If we represent the bones and muscles of the fore-arm by this diagram, we shall see that power is lost by the inclination of the tendon to the lever, into which it is inserted. It represents the lever of the third kind, where the moving power operates on a point nearer the fulcrum than the weight to be moved.

Here A represents the muscle, B the lever, and C the fulcrum. The power of the muscle is not represented by the distance of its insertion *a*, from the

Fig. 21



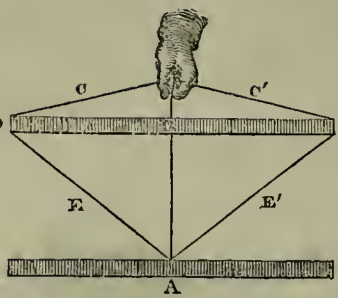
fulcrum C. The line which truly represents the lever must pass from the centre of motion, perpendicularly to the line of the tendon, *viz.*, C, *b*. Here, again, by the direction of the tendon, as well as by its actual attachment to the bone, power is lost and velocity gained.

We may compare the muscular power to the weight which impels a machine. In studying machinery, it is manifest that weight and velocity are equivalent. The handle of the winch in a crane is a lever, and the space through which it moves, in comparison with the slow motion of the weight, is the measure of its power. If the weight, raised by the crane, be permitted to go down, the wheels revolve, and the handle moves with the velocity of a cannon-ball, and will be as destructive if it hit the workman. The weight here is the power, but it operates with so much disadvantage, that the hand upon the handle of the winch can stop it: but give it way, let the accelerated motion take place, and the hand would be shattered which touched it. Just so the fly-wheel, moving at first slowly, and an impediment to the working of a machine, at length acquires momentum, so as to concentrate the power of the machine, and enable it to cut bars of iron with a stroke.

The principle holds in the animal machinery. The elbow is bent with a certain loss of mechanical power; but by that very means, when the loss is supplied by the living muscular power, the hand descends through a greater space, moves quicker, with a velocity which enables us to strike or to cut. Without this acquired velocity, we could not drive a nail: the mere muscular power would be insufficient for many actions quite necessary to our existence.

Let us take some examples to show what objects are attained through the oblique direction of the fibres of the muscle, and we shall see that here, as well as by the mode of attachment of the entire muscle, velocity is attained by the sacrifice of power. Suppose that these two pieces of wood (*fig.* 22.) to be drawn together by means of a cord, but that the hand which pulls, although possessing abundant strength, wants room to recede more than what is equal to one third of the space betwixt the pieces of wood; it is quite clear, that if the hand were to draw direct on the

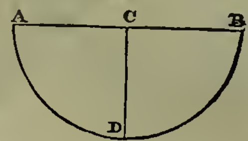
Fig. 22.



cord A, B, the point A would be brought towards B, through one third only of the intervening space, and the end would not be accomplished. But if the cord were put over the ends of the upper piece, C, D, E, and, consequently, directed obliquely to their attachment at A, on drawing the hand back a very little, but with more force, the lower piece of wood would be suddenly drawn up to the higher piece, and the object attained. Or we may put it in this form:—If a muscle be in the direction of its tendon, the motion of the extremity of the tendon will be the same with that of the muscle itself: but if the attachment of the muscle to the tendon be oblique, it will draw the tendon through a greater space; and if the direction of the muscle deviate so far from the line of the tendon as to be perpendicular to it, it will then be in a condition to draw the tendon through the greatest space with the least contraction of its own length.

Thus, if A, B be a tendon, and C, D a muscle; by the contraction of C to D

Fig. 23.

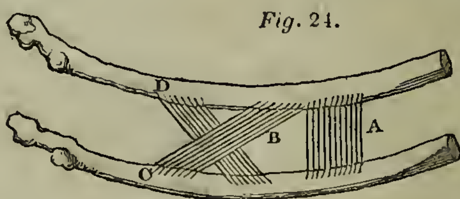


the extremities of the tendon A, B will be brought together, through a space double the contraction of the muscle. It is the adjustment, on the same principle, which gives the arrow so quick an impulse from the spring of the bow, the extremities of the bow drawing obliquely on the string.

To free breathing, it is necessary that the ribs shall approach each other, and this is performed by certain *intercostal* muscles, (or muscles playing between the ribs,) and now we can answer the question, why are the fibres of these muscles oblique?

Let us suppose this figure to represent two ribs with thin intervening muscles. If the fibres of the muscle were

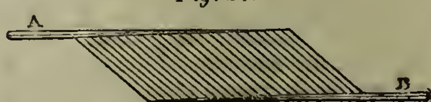
Fig. 24.



in the direction A, across, and perpendicular to the ribs; and if they were to contract one-third of their length, they would not close the intervening space—they would not accomplish the purpose. But being oblique, as at B, although they contract no more than one-third of their length, they will bring the ribs C, D together. By this obliquity of the intercostal muscles, they are enabled to expand the chest in inspiration, in a manner which could not be otherwise accomplished.

In the greater number of muscles the same principle directs the arrangement of the fibres; they exchange power for velocity of movement, by their obliquity. They do not go direct from origin to insertion, but obliquely, thus, from tendon to tendon:—

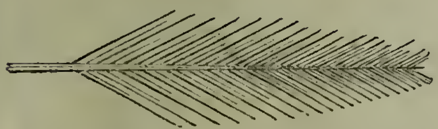
Fig. 25.



Supposing the point A to be the fixed point, these fibres draw the point B with less force, but through a larger space, or more quickly than if they took their course in direct lines; and by this arrangement of the fibres the freedom and extent of motion in our limbs are secured.

But the muscles must be strengthened by additional courses of fibres, because they are oblique; since by their obliquity they lose something of their force of action: and therefore it is, we must presume, that we find them in a double row, making what is termed the *penniform* muscle, thus,—

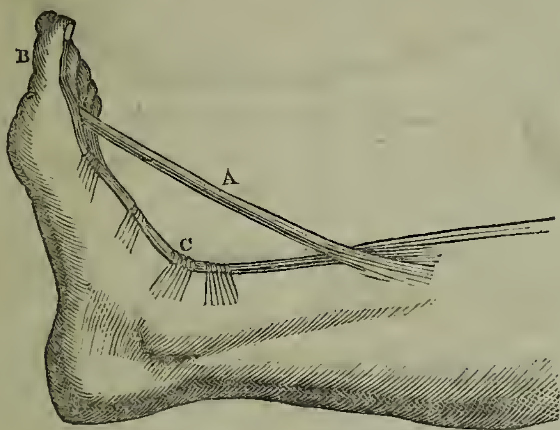
Fig. 26.



and sometimes the texture of the muscle is still further compounded by the intermixture of tendons, which permit additional series of fibres; and all this for the obvious purpose of accumulating power, which may be exchanged for velocity of movement.

We may perceive the same effect to result from the course of the tendons, and their confinement in sheaths, strengthened by cross-straps of ligament. If the tendon, A, (*fig.* 27) took the shortest course to its termination at B, it would draw up the toe with greater force; but then the toe would lose its velocity of movement. By taking the direction

Fig. 27.

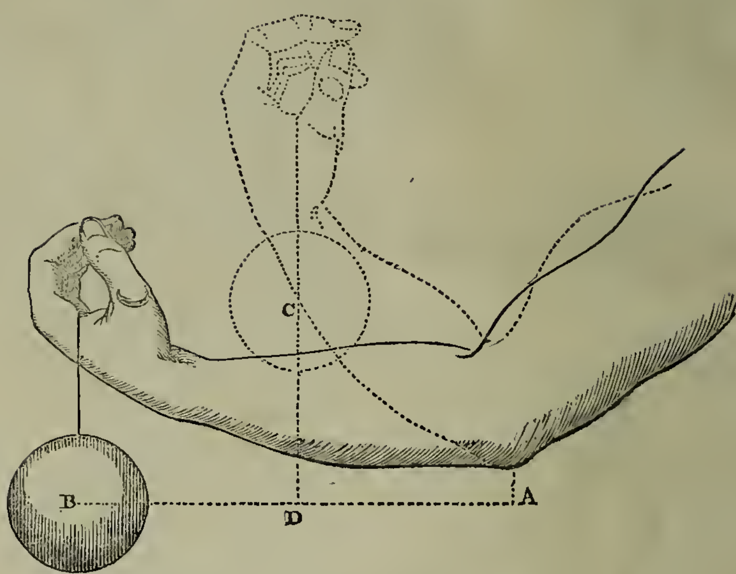


C, close to the joints, the velocity of motion is secured, and by this arrangement the toes possess their spring, and the fingers their lively movements. We may take this opportunity of noticing how the mechanical opposition is diminished as the living muscular power is exhausted. For example, in lifting a weight, the length of the lever of resistance will be from the centre of the elbow joint, A, (*fig.* 28) to the centre of the weight, B. As the muscles of the arm contract, they lose something of their power; but in a greater proportion is the mechanical resistance diminished, for when the weight is raised to C A D, it becomes the measure of the lever of resistance.

A more admirable thing is witnessed by the anatomist—we mean the manner in which the lever, rising or falling, is carried beyond the sphere of action of one class of muscles, and enters the sphere of activity of others. And this adaptation of the organs of motion is finely adjusted to the mechanical resistance which may arise from the form or motion of the bones. In short, whether we contemplate the million of fibres which constitute one muscle, or the many muscles which combine to the movement of the limb, nothing is more surprising and admirable than the adjustment of their power so as to balance mechanical resistance, arising from the change of position of the levers.

In the animal body, there is a perfect relation preserved betwixt the parts of the same organ. The muscular fibres forming what is termed the belly of the muscle, and the tendon through which the muscle pulls, are two parts of one organ; and the condition of the tendon indicates the state of the muscle. Thus jockies discover the qualities of a horse by its sinews or tendons. The most approved form in the leg of the hunter, or hackney, is that in which three convexities can be distinguished,—the bone; the prominence of

Fig. 28.



the elastic ligament behind the bone; and behind that the flexor tendons, large, round, and strong. Strong tendons are provided for strong muscles, and the size of these indicate the muscular strength. Such muscles, being powerful flexors, cause high and round action, and such horses are safe to ride; their feet are generally preserved good, owing to the pressure they sustain from their high action. But this excellence in a horse will not make him a favourite at Newmarket. The circular motion cannot be the swiftest; a blood-horse carries his foot near the ground. The speed of a horse depends on the strength of his loins and hind quarter; and what is required in the fore-legs is strength of the extensor tendons, so that the feet may be well thrown out before, for if these tendons be not strong, the joints will be unable to sustain the weight of his body, when powerfully thrown forward, by the exertion of his hind-quarters, and he will be apt to come with his nose to the ground.

The whole apparatus of bones and joints being thus originally constituted by Nature in accurate relation to the muscular powers, we have next to observe, that this apparatus is preserved perfect by exercise. The tendons, the sheaths in which they run, the cross ligaments by which they are restrained, and the *bursæ mucosæ** which are interposed to diminish friction, can be seen in perfection only when the animal machinery has been kept in full activity. In inflammation, and pain, and necessary restraint, they become weak; and even confinement, and want of exercise, without disease, will produce imperfections. Exercise unfolds the muscular system, producing a full bold outline of the limbs, at the same time that the joints are knit, small, and clean. In the loins, thighs, and legs of a dancer we see the muscular system fully developed; and when we turn our attention to his puny and disproportioned arms, we acknowledge the cause—that, in the one instance, exercise has produced perfection, and that, in the other, the want of it has occasioned deformity. Look to the legs of a poor Irishman travelling to the harvest with bare feet: the thickness and roundness of the calf show that the foot and toes are free to permit the exercise of the muscles

* These *bursæ mucosæ* (mucous purses) are sacs containing a lubricating fluid. They are interposed wherever there is much pressure or friction, and answer all the purposes of friction-wheels in machinery.

of the leg. Look, again, to the leg of our English peasant, whose foot and ankle are tightly laced in a shoe with a wooden sole, and you will perceive, from the manner in which he lifts his legs, that the play of the ankle, foot, and toes are lost, as much as if he went on stilts, and, therefore, are his legs small and shapeless.

And this brings us naturally to a subject of some interest at present: we mean the new fashion of exercising our youth in a manner which is to supersede dancing, fencing, boxing, rowing, and cricket, and the natural impulse of youth to activity.

By this fashion of training to what are termed *gymnastics*, children at school are to be urged to feats of strength and activity, not restrained by parental authority, nor left to their own sense of pleasurable exertion. They are made to climb, to throw their limbs over a bar, to press their foot close to their hip, their knees close to their stomach; to hang by the arms and raise the body,—to hang by the feet and knees,—to struggle against each other, by placing the soles of their feet in opposition, and to pull with their hands. No doubt, if such exercises be persevered in, the muscular powers will be strongly developed. But the first question to be considered is the safety of this practice. We have seen a professor of gymnastics, by such training, acquire great strength and prominence of muscles; but by this unnatural increase of muscular power, through the exercises he recommended, he became ruptured on both sides. The same accident has happened to boys too suddenly put on these efforts.

It is proper to observe, that when the muscular power is thus, we may say, preternaturally increased, whether in the instance of a race-horse, an opera-dancer, or a pupil of the Calisthenic school, it is not merely necessary to put them on their exercises gradually in each successive lesson, but each day's exertion must be preceded by a wearisome preparation. In the great schools, like that at Stockholm, the master makes the boys walk in a circle; then run, at first gently; and so he gradually brings them into heat, and the textures of their frame are composed to that state of elasticity and equal resistance, as well as to vital energy, which is necessary for the safe display of the greater feats of strength and activity. This caution in the public exercises is the very demonstration of the dangers of the system. The boys will not be always under this severe control, and yet it is important to their safety.

We may learn how necessary it is to bring the animal system gradually into action from the effects of very moderate exercise on a horse just out of the dealer's hands. The purchaser thinks he may safely drive him ten miles, not aware that the horse has not moved a mile in a week, and the consequence is, inflammation and congestion in his lungs. The regulation in the army has been made on a knowledge of these facts. When young horses are brought from the dealer they are ordered to be walked an hour a-day the first week, two hours a-day the second week, three hours a-day in the third week. They are to be fatigued by walking, but they must not be sweated in their exercise. Horses for the turf, under three years old, in training for the Derby, are brought very slowly to their exercise, beginning with the lounge; then a very light weight is put upon them, and that gradually increased. Indeed, nothing can better show the effects of exercise in perfecting the muscular action than the consequence of the loss of one day's training. It will bring the favourite to the bottom of the list, and that without any suspicion of lameness, but from a knowledge of the fact, that even such a slight irregularity in his training will have a sensible effect on his speed. Shall the possibility of pecuniary loss excite the jockey to more care for his horse than we, in our rational and humane attention to the education of our youth, pay to their health and safety?

In reflecting on these many proofs of design in the animal body, it must excite our surprise that anatomy is so little cultivated by men of science. We crowd to see a piece of machinery or a new engine, but neglect to raise the covering which would display in the body the most striking proofs of design, surpassing all art in simplicity and effectiveness, and without any thing useless or superfluous.

A more important deduction from the view of the animal structure is, that our conceptions of the perfection and beauty in the design of nature, are exactly in proportion to the extent of our capacity. We are familiar with the mechanical powers, and we recognise the principles in the structure of the animal machine; and in proportion as we understand the principles of hydrostatics and hydraulics, are able to discern the most beautiful adaptation of them in the vessels of an animal body. But when, to our further progress in anatomy, it is necessary that we should study a matter so difficult as the theory of life, imperfect principles or wrong conceptions distort and obscure the appearances: false and presumptuous theories are formed, or we are thrown back in disappointment into scepticism, as if chance only could produce that, of which we do not comprehend the perfect arrangement. But studies better directed, and prosecuted in a better spirit prove that the human body, though deprived of what gave it sense and motion, is still a plan drawn in perfect wisdom.

A man possessed of that humility which is akin to true knowledge, may be depressed by too extensive a survey of the frame of nature. The stupendous changes which the geologist surveys—the incomprehensible magnitude of the heavenly bodies moving in infinite space, bring down his thoughts to a painful sense of his own littleness: " to him the earth with men upon it, " will not seem much other than an " ant-hill, where some ants carry corn, " and some carry their young, and some " go empty, and all to and fro a little " heap of dust."*

He is afraid to think himself an object of Divine care; but when he regards the structure of his own body, he learns to consider space and magnitude as nothing to a Creator. He finds that the living being, which he was about to contemn, in comparison with the great system of the universe, exists by the continuance of a power, no less admirable than that which rules the heavenly bodies; he sees that there is a revolution, a circle of motions no less wonderful in his own frame, in the microcosm of man's body, than in the planetary system; that there is not a globule of blood which circulates, but possesses attraction as incomprehensible and wonderful as that which retains the planets in their orbits.

The economy of the animal body, as the economy of the universe, is sufficiently known to us to compel us to acknowledge an Almighty Power in the creation. What would be the consequence of a further insight—whether it would conduce to our peace or happiness—whether it would assist us in our duties, or divert us from the performance of them, is very uncertain.

* Bacon.

Chapter VII.

Books.

Ray, " On the Wisdom of God manifested in the Works of the Creation," has several chapters on the animal economy.

Archdeacon Paley has composed a work of high interest, by taking the common anatomical demonstrations, and presenting them in an elegant and popular form. His work is entitled Natural Theology; or, Evidences of the Existence and Attributes of the Deity, collected from the Appearances of Nature.

The celebrated Fenelon has, with the same pious object, composed a small duodecimo, in which he draws his arguments from the structure of animal bodies.

Wollaston, in the " Religion of Nature delineated," has the same train of reflection to prove that there can be no such thing as chance operating in and about what we see or feel; and he says, with great propriety, " How may a man qualify himself so as to be able to judge of the religions professed in the world; to settle his own opinions in disputable matters; and then to enjoy tranquillity of mind, neither disturbing others, nor being disturbed at what passes among them?"

Derham, in sixteen sermons, preached in 1711, at the lecture founded by Mr. Boyle, treats at length of the structure of our organs. These are also published, separately, under the title of *Physico-Theology;* and they naturally suggest to learned divines, the expediency of sometimes expounding to their hearers the evidences of design appa-

rent in the universe, as a sure means of enlightening their understandings, elevating their views, and awakening their piety.

This cultivation of the mind, by exercising it upon the study of proper objects, is a man's first duty to himself. Without it, he can have no steady opinion on points of the nearest concern. He is wrought upon by circumstances which ought not to sway the mind of a sensible man; at one time depressed to the depths of despondency, and, at another, exalted into unreasonable enthusiasm. Without such cultivation, were a man to live a hundred years, he is at last like one cut off in infancy.

ANIMAL MECHANICS,

OR,

PROOFS OF DESIGN IN THE ANIMAL FRAME.

PART II.

SHOWING THE APPLICATION OF THE LIVING FORCES

Amongst the least informed people, and in remote villages, there are old saws and rules regarding health, sickness, and wounds, which might be thought to come from mere experience; but they are, on the contrary, for the most part, the remains of forgotten theories and opinions, laid down by the learned of former days. Portions of knowledge, it would appear, confined at first to a select part of society, are, in the progress of time, diffused generally, and may be recognised in the aphorisms of the poor. These are traced to their source only by the curious few, who like to read old books, and to observe how that which is originally right, becomes, through prejudice and ignorance, distorted and fantastical.

If a very little exact knowledge of the structure of our own frames were more generally diffused, charity would be advanced, empirics could hardly maintain their influence, and medical men might have a farther motive to desire professional eminence.

Men suppose that the knowledge of their own bodies must be a science locked up from them, because of the language in which it is conveyed; or they take away their thoughts from it, as from the contemplation of danger, unwilling to survey the slight ties by which they hold their lives. They are like persons for the first time at sea, who shudder to calculate how many circumstances must concur to speed the frail vessel on its voyage, and how little is between them and the deep. It is then a mean and timid spirit that shuts out from our contemplation the finest proofs of Divine Providence. Galen's treatise on the uses of the parts of the human body, was composed as a hymn to the Creator, and abounds in demonstrations of a Supreme Cause; and when Cicero desires to prove the existence of the Deity from the order and beauty of the universe, he surveys the body of man, deeming nothing more godlike, as marking man's superiority to the brutes, than the privilege of contemplating his own condition, since it teaches him the ways of providence, from a knowledge of which come piety and all the virtues.

Although we are writing under the title of Animal Mechanics, the reader must be aware that we cannot proceed much farther, on mechanical principles alone. At least, before we have it in our power to illustrate particular parts of the animal frame, by reference to those principles, we must have the proofs before us that we are considering a living body. It is the principle of *life* which distinguishes the studies of the physiologist from the other branches of natural knowledge. To lose sight of this distinction, is to tread back the path, and to engage once more in the vain endeavour to explain the phenomena of life on mechanical principles. We have taken mechanics in their application to mechanical structure in the living body, because they give obvious proofs of design, and in a manner that admits of no cavil. Yet, although those proofs are very clear in themselves, they are not so well calculated to warm and exalt our sentiments, as these which we have now to offer, in taking a wider view of the animal economy.

In entering on the second department of this treatise, the reader may be startled at the subjects of discussion; but this comes also from ignorance of their nature. Much may be learned from the

observation of things familiar. Their perpetual recurrence banishes reflection respecting them, but it is the business of philosophy to make us alive to the importance of that which we have been accustomed to from childhood, and have, therefore, long ceased to observe with attention.

In the first chapter of this second part we shall continue to examine the operations of the animal body, independently of the agency of the living property. We shall consider it as a mere hydraulic machine. Following the blood in its circle through cisterns and conduit pipes, we shall point out the application of the principles of this science, as we formerly did those of mechanics, and so arrive at the like conclusions by a different course. And as we before found every muscular fibre adjusted with mechanical precision, so now we shall find every branch of an artery, or of a vein, taking that precise course and direction which the experience of the engineer shows to be necessary in laying the pipes of an engine.

Having thus surveyed the mechanical operations of the animal body, and the course of the fluids conveyed through it, on hydraulic principles, we shall consider ourselves as having advanced through the meaner to the higher objects of inquiry, and proceed to show how the principle of life bestows different endowments on the framework; how motion originates in a manner quite different from that produced by mechanical forces; how the sensibilities animate the living properties of action; how the different endowments of life correspond with each other, and exhibit power and design in a degree far superior to any thing that we observed in the mechanical adjustment of the parts, or the circulation of the fluids.

Chapter I

The circulation of the blood, upon the principles of hydraulics.

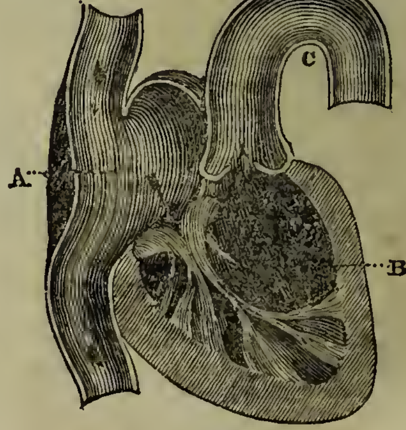
In tracing the course of the circulation of the blood, it is natural to inquire how far the system of reservoirs, pipes, and valves, which form the apparatus for conveying it, are constructed on the principles of hydraulics.

We find this difficulty in the outset, that the vessels containing the blood are not rigid, like those the engineer employs in erecting hydraulic machinery. Instead of resembling pipes which convey water, and which receive the force of gravitation on them, they have both elasticity and an appropriate living power. The artery, the tube which conveys the blood out from the heart to the body, has a property of action in itself. Its elasticity and muscular power must derange those influences which we study in pure hydraulics.

There is to be found, notwithstanding, a great deal that is common to both, when we compare the tubes of an animal body with the hydraulic engine; the capacity of the vessels; the increase, or diminution, of their calibres; their curves; the direction of their branches; —all these ought still to be on the same principles on which experience has taught men to form conduit pipes. We ought not to be indifferent to these proofs of design, because we acknowledge that an infinitely superior power is brought into operation in the animal body, and which is necessary to the circulation of the blood. It renders the inquiry more difficult, but it does not obscure the inferences drawn from the consideration of the whole subject.

We shall first present to our readers the simplest form of the Heart. It is not necessary to detail the more complicated structure of the human heart, where, in fact, two hearts are combined; the fibres of the one continued into the fibres of the other, and the tubes twisting round one another so as to present the form which is familiar to every body. Although there are four intricate cavities, seven tubes conveying the blood into them, and two conveying it out of them, we shall, for the purpose of considering

Fig. 1.



the forces circulating the blood, and comparing the living vessels with pipes, present the heart and vessels as simple; yet with perfect truth, being, in fact, the heart and vessels of animals of more simple structure.

The action of the heart is this: the blood returns from the body by veins into the sinus, or auricle,* A, and distends it; this sinus is surrounded with muscular fibres; by the distention or elongation of these fibres they are excited, and the sinus contracts and propels the blood into the ventricle, B. The ventricle is more muscular; it is, in fact, a powerful hollow muscle; it is excited by the distention, and contracts and propels the blood into the artery, C.

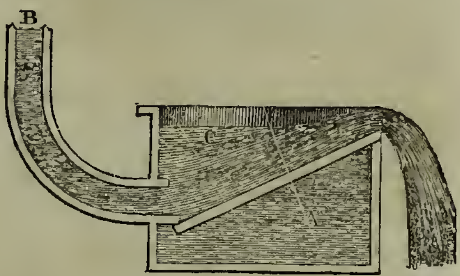
We understand then that every heart must, at least, consist of two cavities alternating in their action; that the vessel which carries the blood to them is called a vein; and that the vessel which carries the blood out from them is the artery.

The first thing that strikes a person examining the heart is the extraordinary intricacy of the cavities, from the interlacing of its muscular fibres, and he naturally says that they appear ill calculated for conveying a fluid through them. There is an attraction between fluids and solids, he might observe, and this attraction is increased by the extension of the surfaces of the pillars and cords which he sees in the interior of the heart.

We must remind him that the blood is coming back from the body, having performed very different offices, in different parts, and has parted with different properties, in the several organs it has supplied. There is in that stream of blood which enters through the vein a new supply of fluid which has come by digestion, the material for making fresh blood, as well as that which has run the circle. These two fluids must be thoroughly mixed together, and, no doubt, this is one of the offices provided for by the intricacy of the interior of the heart.

Again, looking to the recesses of the cavities formed between the fleshy columns, and behind the valves, we might suppose that the blood would remain there stagnant. There are cavities or recesses too in the remote parts of the circulating vessels, where we might suspect that the influence of the stream would not be felt, and a stagnation might take place. But there is attraction between the particles of fluids as well as between the fluids and their containing tubes. Let us see then how, in this figure, a stream of water carried through a cistern of water will, by its friction, draw after it the water in the cistern, and carry it above its natural level, and over the side of the vessel.

Fig. 2.



The stream entering the reservoir, A, by the pipe, B, carries with it all the water, C, which stands above the level of its upper surface. By this we see that the stream of blood entering into the heart, even if its cavities were not emptied at each pulse, as some contend they are, would draw out the blood from its recesses, so that no part could remain stagnant, but, on the contrary, all would be carried in eddies round the irregularities until they took the direction of the great artery, in which they would be perfectly combined.

The next thing to be noticed partakes of the nature of a mechanical provision —we mean the action of the valves.

We must here remark, that the opening into the ventricle is very different from that which leads out of it—the latter being much smaller. Medical writers describe this as if it were nothing to them, and a mere accident. But it must be recollected, that a stream of water entering a reservoir, is in a very different condition from that which is going out of it; it is on this principle that the mouths (*ostia* is the anatomical term) of the ventricle are differently formed, and it is this difference, which makes the structure of the valves which guard those passages so dissimilar and so appropriate. Without attention to this, we should follow our medical authorities, and call this variety in the mechanical adaptation a mere playfulness in nature.

* Auricle, from *auricula*, the flap of the ear, is a name given to the sinus, because a corner of it hangs over like a dog's ear.

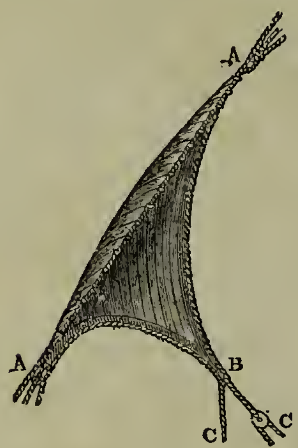
It is more agreeable to us, to see a precision of design visible at the first step of this inquiry.

The valves of the heart are regular flood-gates which close the openings against the retrograde motions of the blood. They are not all of the same mechanical construction; and their difference deserves the reader's attention as proving design in this hydraulic machinery.

The valve which we have first to describe, closes the opening betwixt the auricle or sinus, and the ventricle, and prevents the action of the ventricle propelling the blood back again into the auricle.

It is a web or membrane, resembling a sail, when bagged by the wind. The blood catches the margin of this membrane, and distends it as the wind does the stay-sail, or gib, of a vessel, which it much resembles, being triangular and pointed. There are three of these membranes, and the valve is called *tricuspid*, or three-pointed. Three membranes then, of this kind, combining and being floated back upon the mouth of the opening, effectually close it.

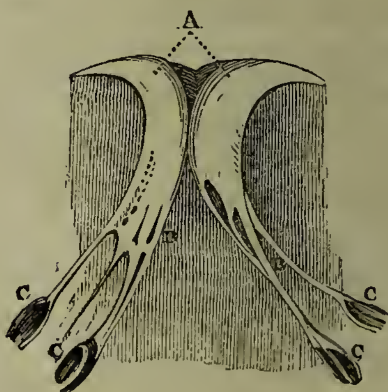
Fig. 3.



The illustration of the action of these valves by a sail, is so perfect, that if the reader will have patience to attend to those little contrivances which the mariner finds necessary for strengthening his canvass, and giving to it the full influence of the wind, he will have an accurate idea of the adjustment of these floating valves.

To carry on the comparison—one edge of the stay-sail is extended upon the stay A A, and tied to it by *hanks*. The edges of the sails called the *leeches*, have a *bolt-rope* run along them; and on the edge where it is attached, the canvass is strengthened by being hemmed down or tabled. In the same way as the foot of the sail, or lower margin, is strengthened with the bolt-rope, just so are the valves strengthened at their edges and their corners. Where the two ropes join in the loose corner of the sail, they form a clue—a loop to which tackle is attached; the valve has such a corner, so strengthened, and has a cord attached. The corners of the sail are strengthened by additional portions of canvass called patches; so are the valves strengthened where their tendons are infixed. To the corner or clue, B, ropes are attached which are called the *sheets*, C C. These being drawn tight, spread out the foot of the sail to one side or the other, according to the direction of the wind, and the tack the ship is on; the valves have also their tackle; and, in short, we shall find a resemblance to all the parts of a sail in the valves of the heart.

Fig. 4.



One edge of the triangular valve is tied to the margin of the opening, as one of the leeches of the sail is attached to the stay; the opposite corner is loose, and floats, as the sail does in tacking, until the blood, bearing against it as the wind bears against the sail, bags and distends it; the corner is then held down by tendons, for there are cords attached to the corner of the valve, as well as to the corner of the sail. These the anatomist calls *cordæ tendineæ*, B B, which in their office have an exact resemblance to the ropes called the sheets of the sail. They are delicate tendons attached to the margin of the valve, and they prevent the margin from being carried back into the auricle.

Here we find a very beautiful muscular apparatus which is necessary to the perfect adjustment of these cords. The cords are attached to small muscles called *columnæ carneæ*, C C, or fleshy columns, which at their other extremities are incorporated with the muscular wall of the ventricle itself. The use of these muscles is now to be explained. Had the tendinous cords of the valves been tied to the inside of the wall of the ventricle, without the intervention of these muscles, as the walls of the cavity approach each other during their contraction, the tendinous cords would have been let loose, and the margins of the valves carried back into the auricle. But by the intervention of these muscles, they are pulled upon and shortened in proportion as the sides of the cavity approach each other.

On the whole, then, we perceive, that this apparatus, which is as intricate as the rigging of a ship, consists of a variety of fleshy columns and cords, many of which, in fact, run across the cavity of the ventricle.

We are about to exhibit another form of a valve, much simpler, and yet we are bound to believe equally effectual; which tends to support the opinion expressed above, that besides preventing the retrograde motion of the blood, this intricate apparatus of the ventricle is intended more effectually to agitate and to mix the different streams.

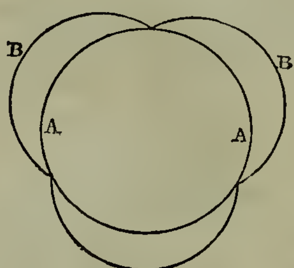
At the root or origin of the great artery, called the *Aorta*, there is a firm ring to which the valves now to be described are attached. The necessity of this will appear evident, since, if the ring could be stretched by the force of the heart's action, the valves or flood-gates would not be sufficient to close the passage; their conjoined diameters would not equal that of the artery which they have to close. These valves are three in number: they are little half-moon shaped bags of thin membrane, which are thrown up by the blood passing out from the ventricle, but by the slightest retrograde movement of the blood their margins are caught, and then, being distended or bagged, they fall together, and close the passage. There are some curious little adjuncts to these valves, which ought to be explained, as showing the accuracy of the mechanical provision.

When the margin of the valve is thrown up by the blood passing out of the heart, it is not permitted to touch

Fig. 5.

or fall flat upon the side of the artery, for if it did, it would not be readily caught up by the blood that flows back; there is therefore a little dilatation of the coats of the artery behind each valve by which, although the margins of the valve be distended to the full circle, they never cling to the coats. These valves, then, are never permitted to fall against the coats of the artery, and therefore they are always prepared to receive the motion of the refluent blood.

Fig. 6.



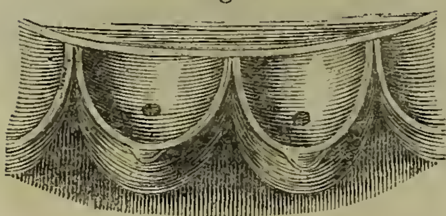
Let this figure represent a transverse section of the root of the aorta, A A, the inner circle, is the margin of the three valves thrown up to let the blood pass. B B B are three semicircular bags formed by the dilatation of the coats of the artery at this part, receding from the margin of each of the valves—consequently, in such a manner as to leave a space between the valves and the sides of the vessel.

To strengthen the valves, a tendon runs along their margin like the bolt-rope or foot-rope along the edge of a sail, and these ligaments are attached to the side of the artery, and give the valve great strength.

Fig. 7.

These valves, we have said, are semilunar, consequently, when they fall together, there must be a space, A, left between them. If we put the points of the thumb, fore and middle fingers, together, there is a triangular space left between them ; such a space between the convexities of the three valves would be a defect.

Fig. 8.*



Three little bodies like tongues are therefore attached to the middle of the margin of each valve, and these falling together, when the valve is shut down, perfect the septum and prevent a drop of blood passing backwards.

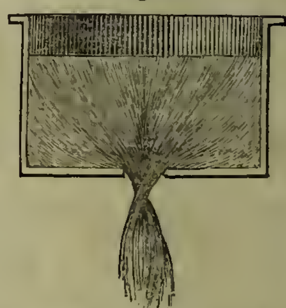
The valves have no power of accelerating the motion of the blood; they only prevent its retrograde motion, and cause the whole power of the heart to be employed in directing the blood forwards in the course of the circulation. But when they are ruptured, when the valve first described is rent, or the cordæ tendineæ are broken, then the membrane, which we have said is like a sail, is carried back from the second into the first cavity. It is like the sail torn from the sheets and flying out before the wind: the effect is terrible: the pulse of the heart, the whole force of which should be given to carry the blood forwards in the arteries, has half its force directed backwards upon the veins.

In the same manner the semilunar valves in the root of the aorta may have their margins torn. We have described the margin of these valves to be strengthened by a tendon or cord run along their edge, like the rope which is sewed to the edge of a sail. There is an obvious intention in strengthening the valve here; but when textures of this kind become impaired in the human frame, this may give way and be torn, and then the reaction of the artery, when the heart has given its stroke, is lost; for, instead of impelling the blood forwards, the blood runs backwards into the heart. The effect of these accidents is extreme debility of circulation, with symptoms varied according as the defect falls on the circulation through the lungs or through the body—that is, whether on the right or the left heart of man. But such accidents are rare, and never take place until disease has impaired the strength of what we may call the tackle of the valve.

The next remark is founded more directly on the hydraulic principle.

This ring and these valves at the beginning of the great artery—imply a certain constriction, or diminution of the tube at this part; and we have now to show—that such a contraction of the tube at this precise part does not diminish the diameter of the column of blood. This appears an inconsistency; but if a stream of water flow from a cistern, through a hole in that cistern, the column of water will be diminished at a certain point of its exit.

Fig. 9.



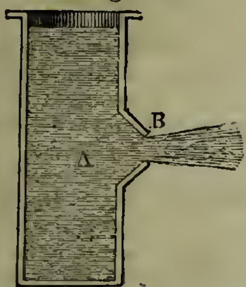
The water flowing through the bottom of the cistern may be represented by converging lines; and their united forces impelling the stream forward, contract it just beyond the exit—the *Vena Contracta*. Nature, taking advantage of this law, has constructed the narrow ring which we have shown is necessary to the accurate adjustment of the valve, at the precise part where the blood, issuing from the cavity of the ventricle, is necessarily contracted to the smallest space. The column of blood would be

* *Fig.* 8 represents the artery open, and the semilunar valves, like little bags, attached to the inside.

contracted at this point, even if there were no coats of the artery to confine it there.

We had thought of this as a thing indicated by reasoning, but we find that an appropriate experiment has been made which proves it.

Fig. 10.



A being the side of a reservoir, and B a short tube giving issue to the water, it will deliver as much water by this conical constructed mouth, as if the tube were of equal diameter with the hole in the reservoir. The reader will perceive how satisfactorily this indicates what is designed by the difference in the size of the mouth of the ventricle which gives entrance, and that which gives issue to the blood.

With a view to explain the motion of fluids in tubes, and finally the motion of

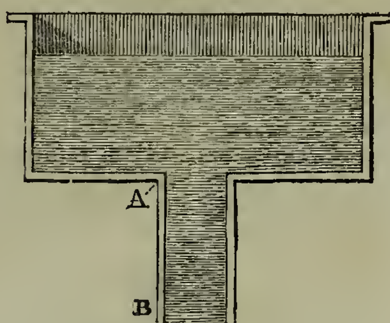
Fig. 11.

the blood in the blood-vessels, let us consider what takes place in the motion of the column of water which is not contained in a tube.

When water is poured out, and descends in an uninterrupted stream, the column contracts as it descends, until it has acquired such a velocity, that the atmosphere opposes it and scatters it; we do not mean the contraction illustrated by *fig.* 9, but that gradual diminution of the diameter of the stream, owing to the height from which it falls. We apprehend that this is on the principle, that falling bodies are accelerated as the square root of the height from which they fall. The stream being more rapid at its lower part, is necessarily smaller in diameter, until having acquired considerable velocity, the resistance of the atmosphere separates its filaments, and it becomes broader again.

A very different appearance is presented in a jet d'eau; here the ascending stream widens as it ascends. The explanation of this we conceive to be, that the fluid is retarded as it mounts, and that the stream propelled from below is forced between the filaments* of the column above, and disperses them, so as to give the column a conical form.

Fig. 12.



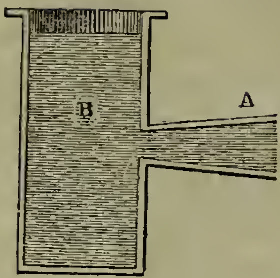
This reservoir will be emptied more rapidly if, instead of a hole in the bottom at A, the water be discharged by a tube, A B, of the diameter of the hole.—Here the column of water being perpendicular, it will be accelerated at its lower part; but instead of diminishing its diameter, as it would do, if not confined by a tube, it will draw an additional volume of water down, and accelerate the discharge.

It will be very different if the force be altogether from behind, as when water is propelled into a horizontal tube.

The tube A being conical, will discharge more fluid from the reservoir B

* Those who treat of hydraulics divide a column of water into ideal lesser columns, which they call filaments, with a very different meaning from the fibres of the anatomist.

Fig. 13.



than if it had been of equal length, and its diameter throughout the same as at its commencement. Because, as it appears to us, the weight of the descending column being the force, and this operating as a *vis a tergo*, it is like the water propelled from the jet d'eau, and the gradual expansion of the tube permits the stream from behind to force itself between the filaments, and disperses them, without producing that pressure on the sides of the tube, which must take place where it is of uniform calibre. These principles will give great interest to the following fact.

The celebrated John Hunter took great pains to prove that the artery had its diameter enlarged as it proceeded from the heart, and that the areas of the branches of an artery were greater than the diameter of the parent trunk.

That is to say, the section of the trunk at A, was not so great as the two sections at B, taken together; that the

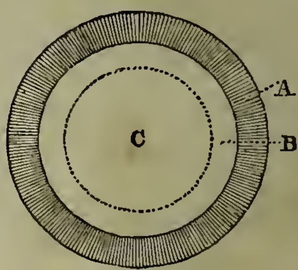
Fig. 14.

two sections at B taken together, were not so great as the four sections at C; that the conjoined diameters, therefore, of the branches of an artery were greater than the diameters of the artery itself. This fact has been sometimes expressed by saying that the artery was a cone with its apex in the heart.

When we stand by a rapid river, we can perceive that the surface of it is not level. The stream is rapid in the middle, and there the water is highest. The friction of the water against the bottom and the sides, retards the stream, whilst the greater velocity of the current in the centre, draws the water to it, which is the reason of its elevation there.

For the same reason, if an engineer estimate the quantity of fluid to be delivered through a tube without estimating the friction of the sides, he will be disappointed in the result of his calculation; for, as the water of the river is delayed by the bottom and sides, so is the fluid in the tube retarded, by

Fig. 15.



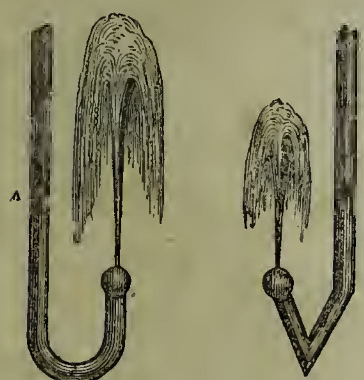
the attraction or friction between the water and the tube. And, if we can imagine a section representing the tube and the flowing water, A will be the solid tube, B the water retarded or arrested by the friction against the tube, and the space C, within the inner circle, would represent that part of the stream which is in uninterrupted flow. The engineer will therefore lay a tube larger than would be necessary, were there neither attraction nor friction between the solid and fluid. It must farther appear that the smaller the calibre of the tube, the surface of attraction or friction will be proportionally greater. Does not this explain the anatomical fact which we have been contemplating, that the area of the smaller branches is comparatively larger than the trunk from which they are derived?

Two beneficial effects result from this; for we must observe that the blood-vessels of the body are reservoirs

as well as conduit-pipes. A man of middling stature has 33 lbs. of blood in his circulating vessels: if the vessels did not enlarge as they receded from the heart, there would be no place for the deposit of this great quantity of blood. The advantages, then, of this particular form are, *first*, that a quantity of blood necessary to the economy is contained within the vessels; and, *secondly*, that the blood is more easily urged forwards by the action of the heart. The reader will not now be surprised in learning, that a pipe of a conical form, that is, enlarging as it proceeds, gives the least interruption to the flow of water from a reservoir.

Water flowing in a tube will be retarded by any sudden angle in the tube. If the ajutage of a jet d'eau have not a gentle and uniform sweep where it is turned, the jet of water will not reach the height which it ought to do by calculation of the height of the reservoir of water from which it descends, it will

Fig. 16.



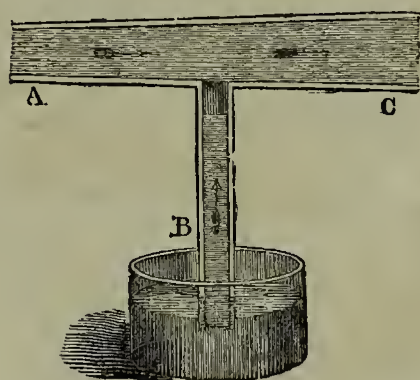
go higher from the tube A than from B. This circumstance explains the uniform and parabolic curve which the great artery of the body takes in first ascending from the heart. It explains also why the branches of the great artery go off at different angles, according to their distance from the heart, or, in other words, why they pass off at smaller angles with the stream the farther the artery recedes from the heart.

In the distribution of water-pipes, it is very necessary to attend to the angle at which the small pipe is attached to the greater one, not only because a pipe being bent abruptly causes loss of motion from the impulse of the fluid against the side, but also from another well known law of hydraulics

If a pipe be fixed into another so as to join it at an angle contrary to the direction of the stream, the discharge into that lateral branch from the larger tube will not only be much smaller than we might estimate by the diameters of the tubes, but, in certain circumstances, it will discharge nothing at all; nay, on the contrary, the water would be drawn from the lesser tube into the greater, until the lesser tube be emptied, and air be sucked in.

Bernouilli found that when a small tube B was inserted into the side of a horizontal conical pipe A, in which the water was flowing towards the wider

Fig. 17.



end C, not only none of the water escaped through the small tube, but the water from a vessel placed at a considerable distance below was drawn up through the tube B into the pipe A.

With these facts before us, we turn with interest to what the anatomist too often contemplates with unconcern, we mean the different curves in the branching of the arteries and veins; for by this law of hydraulics, the junction of the branches and trunks of the arteries and veins ought to be different, as the one vessel, the artery, carries the blood out from the heart, that is, from trunk to branch—and the other vessel, the vein, carries it in the opposite direction towards the heart, or from branch to trunk.

And in matter of fact, their branchings are very different, and characteristic of the vessels.—We have heard a teacher of anatomy express himself in this manner. "The arteries are active and powerful vessels, which carry the arterial blood out from the heart—and they receive the forcible impetus of the heart.

When they are wounded, the man bleeds to death;—therefore, nature conveys these vessels into the recesses of the body, taking advantage of every protecting bone—conveying them so that the bones and the muscles protect them. There are no irregularities in their course, and their branches go off at a determined angle, and never irregularly; but the veins," he would continue, "are vessels of less importance—they convey the blood back to the heart, with a languid motion, and if they are wounded the blood flows with so diminished a force that you can stop it with the pressure of your finger; accordingly, nature is more negligent of them, they run in all their courses irregularly—some deep, some superficially; and their branches join their trunks with awkward irregular curves and elbows."

This is in good feeling, and is in part true; but it contains somewhat of the error which runs through most anatomical discourses, of supposing things are irregular, as if the objects in view were inartificially and imperfectly attained. From inattention to the hydraulic principle, he seemed not to have considered, that the connection of trunk and branch must vary according to the direction of the stream,—that the direction of the branch, which is adapted to lead the stream from the trunk into the branch, must be altered, when the design is to convey the fluid from the branch into the trunk.

Fig. 18.

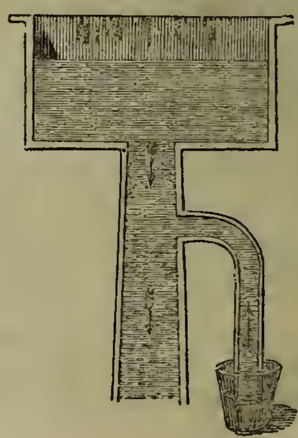
1 2

The reader will now understand, that the branch of the artery (*fig.* 18, *No.* 1.) gently diverges from the direction of the stream, while the branch of the vein, in *No.* 2, enters abruptly and at right angles. We may illustrate this, by observing, that if we could suppose the vein substituted for the artery, and the artery for the vein—if the vein carried the blood outwards, instead of towards the heart, and the artery conveyed the blood back to the heart, the blood could not run in the circle; it would be retarded, and congestion would take place, somewhere in its course.

We have seen by the demonstration above, that if the veins of the human body were rigid tubes, and if a hole were made in their sides, air might be drawn in, instead of blood flowing out. This is a matter of vital consequence, for if a very little air be blown into the veins of an animal, it dies in an instant, and there is no suffering nor struggle, nor any stage of transition, so immediately does the stillness of death take possession of every part of the frame.

In conversation with Napoleon's celebrated surgeon, Baron Larrey, on the case of a young man wounded in the neck, he said he had no hesitation in declaring the cause of death to be, air drawn in by the veins of the neck, and he quoted instances occurring at the battle of Wagram. These circumstances greatly increase the interest of an experiment made by Dr. Barry, who found that on introducing a tube into the vein of the neck, and placing the other end of the tube in a vessel of water, the water rose during inspiration. The difficulty of explaining this, arises from those veins being membraneous tubes, and consequently compressible; but in the act of inspiration, not only are the ribs and breast-bone raised, but the muscles of the neck attached to the collar-bone rise from the veins of the

Fig. 19.

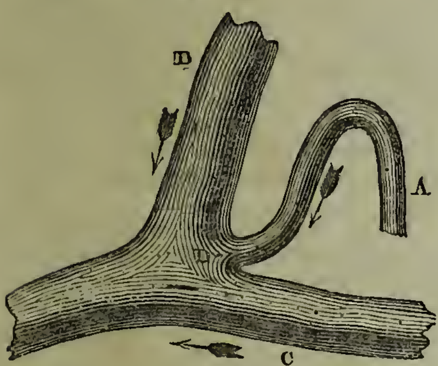


neck. By this means, instead of suffering the compression of the incumbent parts, the atmospheric pressure is taken off the veins, they are brought to the condition of rigid tubes; and the principles of hydraulics explain the rest. Thus *fig.* 19 is a reservoir emptied by a perpendicular tube, into which a smaller tube is inserted. The water descending by the larger tube, will draw the water up through the lesser tube, so as to empty the glass, in which its lower end is immersed.

We shall here give an example of the manner in which the trunk of the absorbent system joins the venous system, a circumstance which has not escaped the notice of anatomists. The absorbing or lymphatic system, consists of a set of vessels different from arteries and veins, which imbibe by a sort of capillary attraction at their extremities, and convey their fluids towards the centre, without any such impulse as the proper blood-vessels receive from the heart. The stream in the trunk of this vessel has no force to impel it into the stream of blood in the veins; it enters, therefore, in this manner.

A is the trunk of this system, called the thoracic duct, B is the great jugu-

Fig. 20.



lar vein descending from the head, and C the great vein coming from the arm. These veins join at an angle, and the streams from them, in the direction of the arrows, leave a point between them at D, where there is no pressure. If two tubes enter into a larger tube obliquely, and the water be flowing from the lesser tubes into the greater one, and if a hole be bored at the angle of their union, the water will not escape at that hole. Therefore, the fluid from the thoracic duct A, meets with no impediment at the point D; when entered, we have seen, by a former diagram, how the attraction of the more forcible stream will draw the contiguous fluid after it. By this contrivance, if we may use the word, the fluid in the absorbing system finds access to the red blood, and is carried into the heart.

We might continue this subject, by considering the influence of respiration on the circulation; but we shall pursue the enquiry into the hydraulic principles, as applicable to the iirculation, independently of pneumatics.

The law of inertia, which is of easy comprehension as it regards solids, is also applicable to fluids; it is easier to keep a column of water in a pipe in motion, than to put it into motion from a state of rest.

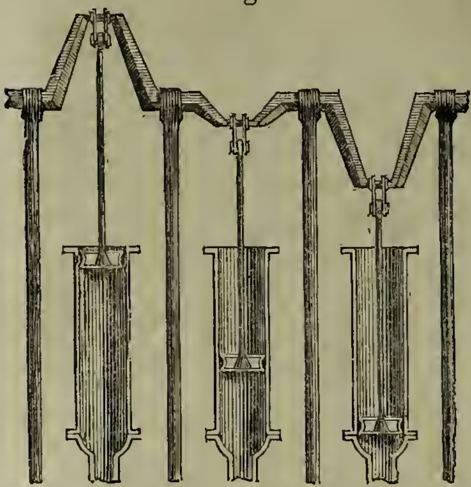
In a forcing pump, when after each movement of the piston the column of water becomes stationary, power is unnecessarily lost by bringing the column of water, which is in this state of rest, again into motion; but if a second blow of the engine be given to the column of water whilst it is yet moving, it is found to be more easily pressed forward, and no part of the force is lost in urging it from a state of rest into motion. This is evinced in the contrivances of the engineer. He employs two forcing pumps instead of one, and he so applies his lever, as to operate alternately on the one and the other; to the end that the water in the pipe may be kept in uninterrupted motion. Let us apply this principle to the circulation of the blood.

If the heart were the only power forcing on the blood, there would be a cessation of motion after each pulse of the heart, and therefore a great part of its power would be lost. This explains why there is a power in the artery as well as in the heart. The artery being muscular, seconds the operations of the heart; its muscularity, and the muscularity of the heart are powers exercised alternately, and which, acting like the double stroke of the engine, permit no interval to the motion of the column of blood. If the heart had to act upon a column of blood at rest, not only much of its force would be unnecessarily exhausted, but it would be excited to propel an inert body, and a dangerous shock would arise from the resistance.

If we pursue this subject, and inquire what is essential to such a hydraulic machine as we are contemplating, we shall perceive that the engineer meets with a difficulty in adjusting the powers

of his two pumps, and finds an interval, or pause, in the application of their forces.

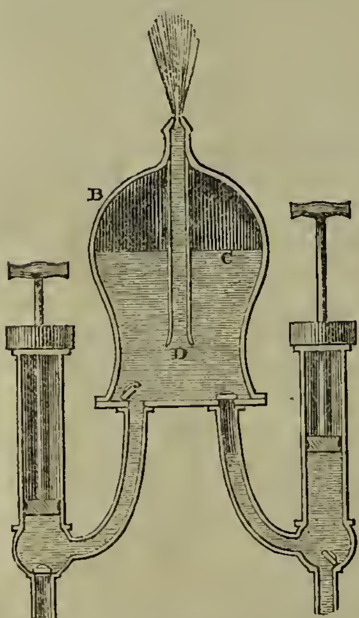
Fig. 21.



To obviate this, he makes three cylinders, the pistons of which are moved by a crank, which so orders the descent of the pistons as to fill up this interval, so that one of the pistons shall be always descending; and these pumps propelling the water into a common tube, there is no interval to the motion of the fluid through it.

By this example we are led to look for something corresponding in the ma-

Fig. 22.



chinery of the circulation. We find no third active power, however; yet we find a quality in the blood-vessels which answers the purpose much better. But to comprehend this, we must observe that the engineer has a more admirable contrivance than this of a third pump to adjust the action of the other two.

He confines a body of air which, by its elasticity, performs the office. The pipes of two forcing pumps are carried into the reservoir B; they convey the water up to C, by which time the air is compressed, and its elasticity thereby increased, that elasticity is exerted without interval, and, acting on the water C, propels it into the tube D uninterruptedly.

Just such an elastic property is possessed by the arteries. The great artery which goes out from the heart, as we have had repeated occasion to observe, makes a sweeping curve; it is capacious, and is the most perfectly elastic of any thing in nature. Here then we have the three powers which the engineer finds necessary to employ. We have the alternate action of the heart and artery, and we have an elasticity which, though passive, is essential, both to the uniform flow of the blood, by filling up the interval in the action of the two powers, and to the safety of the engine itself; for without this elasticity there would be such a jar as must speedily destroy the mechanism.*

There is nothing more admirable than the influence of this elastic power; it is greatest in the coats of the artery near the heart, weaker in the coats of that artery as it recedes from the heart; this very evidently declares its use: but we shall take a more sufficient proof, although an unhappy one.

As life advances, the arterial system loses much of its elasticity, and becomes rigid. This is so common an occurrence that we can no more call it a disease, than the stiffened joints of an old man; it is the forerunner or the accompaniment of the decline of life. But this sometimes takes place too early in life, and to an extreme degree; and from its effects we must call it morbid; for it not unfrequently happens that the muscular power of the heart being still entire and vigorous, the arteries can no longer sustain it. They are not now endowed with that power which, yielding

* But does the blood flow uniformly? Not precisely so in the arteries, since the stroke of the heart is more powerful, or rather more concentrated, than that of the arteries. During the contraction of the ventricle of the heart the artery is dilated; but it is never emptied; and the flow of the blood forwards in the course of the circulation is not for an instant interrupted.

to the heart's action, resists, and recoils the more it yields — which takes off all sudden shock, and which in yielding wastes no power, since on its recoil it gives as much force to the acceleration of the blood, as was lost of the heart's action. The artery then becoming rigid, yields indeed to the heart's impulse, but has no recoil. It is permanently dilated or enlarged. It is now called aneurismal. A stronger impulse from the heart, excited by inordinate action or passion, chips and bursts the now rigid coats of the artery. If the breach be sudden, it is death; if it be gradual, a pouch forms—a true aneurism. And now we have the proof we require; for this bag coming to press upon the solid bones, they are destroyed. That action of the heart which was so lightly and so easily borne whilst the vessels were elastic, now beating upon a solid structure, in a short time destroys it. Thus we are led to a more accurate knowledge of the fine adjustment of the active and resisting properties in the circulating vessels during youth and health, by what takes place on a very slight derangement of those powers.

Chapter II.

The Illustrations from Mechanics may be carried too far. Peculiar properties of Life in the Body. They differ in quality. They have an adjustment to each other, more admirable than the Mechanical connection.

We are the more desirous of entering upon this subject, that we may prevent the reader from founding a false conclusion upon the very mode in which we have hitherto proceeded, that of showing design in every part of the animal structure by taking our illustrations from the mechanism of the body.

When we have admired the connections of the several parts, or organs, thus made manifest by comparison with machinery, we may go too far, and say, that the material structure and mechanical relation are to be found in still greater minuteness and perfection in the finer textures of the body, proceed to call this organization, and erroneously conclude, that out of organization comes Life. The very term organization misleads; yet it implies something constructed, in which one part cooperates with another; but nothing more. Taking the body as a whole, there are undoubtedly instances of such cooperation, but it is in vain to seek the explanation of life from this; since life exists in simple and uniform substances, where there is neither construction nor relation.

Now, although there are mechanical construction and relation, as we have seen, in bones, muscles, and tendons, the phenomena of the body result from a dependance established among the living properties, not the mechanical. The highest medical authorities have seen reason to conclude that life is an endowment, not resulting from organization or construction, but, on the contrary, producing it; in other words, that the living principle attracts the new matter, arranges it, and, in order to its continuance and perfection, alters it, and effects a continual revolution in it. For there is nothing more curious than the uninterrupted and rapid change of the material of the animal body, from the first pulse of life to the last breath that is drawn; of which we shall give abundant proofs before we close this inquiry.

In first approaching the subject we are blinded by familiar occurrences, and cannot comprehend all the links by which the visible phenomena of the living body are produced. Probably most of our readers believe motion to be a necessary consequence of life, and the very proof of its presence. The peasant stirs up an animal with his staff, and if it does not move he is satisfied that it is dead; and such is the experience of mankind. We do not reflect that many different qualities of the living powers must be exercised before sensibility is shown in its visible sign, the motion of the creature. It is not necessary that the parts shall lock into each other like the cogs of wheels;—the connections established are of a different kind altogether. Each part possesses a property of life entirely distinct from the other, and this property of life may exist in the individual part (for a time at least) without that cooperation of the whole which is necessary for the motions of the animal.

This quality of life is, in one respect, like gravitation in matter; that is, when the mass is broken into parts, each division has its proportion of the endowment, and so the separated parts of a living creature possess life. But here the resemblance ceases; gravitation is the same quality in every part, and uniform in its effects, whilst the life is exhibited

by qualities differing in every part of the animal body. Did these parts possess qualities exactly similar, they would remain at rest, and though combined, they would not influence each other. It is the different powers brought into combination that produce the motion of the whole animal.

If a man fall into the water, and is dragged out motionless, and has ceased to breathe, each part of his body may still possess its property of life. Although the combinations have been destroyed, he may be revived by exciting action in some part of his system. Life still remains in brain, and nerves, and heart, and arteries, and in the muscles, which should enable him to breathe; but the mutual influence, the bond of their united operations, is broken. We may take the analogy of a machine, and say that the wheels are stopped; but this is in fact a very different thing; it is the operation of the living influence that is stopped; for we repeat that nature (by which, of course, is always to be understood the Author of Nature) has combined the organs not mechanically, but by properties of life.

Artificial respiration draws after it the action of the heart, because the sensibility of the heart is made respondent to the lungs. Pulsation of the heart, excited by the motion of the lungs, is followed by the action of the arteries; these organs in operation, drive the blood through the frame, and by the circulation the susceptibility of each part to impression, which had been weakened, is restored. Action and reaction are reestablished; but these actions are not like those of a machine, they are living properties; sensibility in one part, contractility in another; and after a variety of these internal sensibilities have been for some time in operation, the man gives outward token of recovery.

So a person recovering from fainting, after sobbing and irregular breathing, has the respiration renewed; in succession other parts recover their sensibility and resume their places in the circle of relations; the skin is capable of being stimulated, and the limbs are capable of motion; the eyelids are opened; by and by the nerve of the eye is sensible to light, and the nerve of the ear to sound; and, finally, the faculties of the mind are roused, and its control over the body reestablished. The whole separate endowments of life in the different parts resume their offices;—the last in the train; only, the property of the muscle to contract is alone observed by the uninformed, and voluntary motion is the token of entire restoration.

We can imagine a half-learned person to act very foolishly in the attempt to restore the apparently drowned. He has been told that we draw in vital air, and breathe out what is unfit to support life; he imagines that it can be of no use to distend the lungs of the drowning person with his own breath, and precious time is lost. Whereas, the mere distension of the chest, that is, of the lungs, followed by the compression of the chest, and again by the distension, and so on alternately, is the *play of the lungs*, which by sympathy draws the heart into action, and in succession all the vital organs. This is not what chemistry teaches; chemistry shows us that the vital air influences the blood; and it is true that the blood, being refreshed or impregnated with the vital air, renews the properties of life. But this effect on the blood could never take place, unless there were some previous consent or sympathy, putting the organs into operation. We repeat that the consent of organs is not the effect of mechanical adaptation, or of chemical action, but of relation established among the vital properties.

If a man be struck by lightning, he has not merely the vital operation of respiration stopped, as in the case of the drowning man, in whom every organ continues to possess its property of life; he is not like a man struck on the head, where one vital organ is so disturbed that the circle of vital actions is broken; in this instance the electric fire passes through every fibre and every organ; all the qualities of life, whether residing in the brain, nerve, or muscle, are instantaneously destroyed; and the moment of death is the commencement of dissolution.

Mr. John Hunter illustrated this somewhat familiarly. If you bruise the head of an eel, its body writhes; but if it be taken by the tail, and struck on the flag-stone, so that every part of its body receives the shock, then all the parts are killed, and it remains motionless. When an animal is killed by that violence which injures one important organ, the property of life remains for a certain time in every part; those parts have no correspondence, and there is no outward token of life; but the vital

principle is still capable of exhibiting one of its most important properties; it arrests the operation of those chemical affinities which belong to dead matter.

Thus the reader perceives, that, although he be led on to comprehend the design or intention manifested in the structure of the body by mechanical instances, or comparisons, it is when we contemplate the influence of the living principle, that we have a higher conviction of the Omnipotence, which has formed every creature, and every part of each creature, with that appropriate endowment of life, which suits it to act its part in the general system.

We must learn to distinguish between the death of the animal, and the death of the parts of the animal—between apparent death, and dissolution, or the separation of that quality which distinguishes living matter.

Viewing the subject generally, as Mr. Hunter said, there are not two kinds of matter, but two conditions of matter. It is at one moment forming beautiful combinations, as in the flower, through the principle of life, and, at another, it is cast away as noxious, undergoing changes by decomposition, from chemical processes solely. The want of combination in the whole animal body exhibits apparent death. The loss of life in all the parts of an animal body, is absolute death, and the material becomes subjected to the influence of the chemical affinities, instead of being urged into motion by life.

The jackstone produces motion in one part of a machine; that, varied by mechanical influence, is communicated to a second; from the teeth of one wheel it is communicated to the corresponding leaves of the pinions, and from the pinions to the fusees. But what a base notion it is to suppose that the mere property of weight in the jackstone is like the influence of life!

The weight is the power, in the language of mechanicians; but it does not reside in the parts of a machine, nor does it exhibit different qualifications in these parts. Separate them, and they are nothing. On the contrary, no one part of an animal body is in this manner dependant on another for its property of life. The property is inherent in the part itself, and the wonderful thing is that each property in the several organs corresponds with the others, so as to form a circle of vital operations. There is no transmission of power, in all this, from part to part—no train of connection to be traced as from the jackstone, or the spring, along the parts of the machine. There is, therefore, in truth, no resemblance between machinery and the influences in operation in a living body. What is to be admired in a living body is not merely the adaptation of bones, muscles, and tendons, forming a mechanical apparatus, but rather the different qualities which life bestows upon different parts; these qualities put the parts into relation each according to its place in the circle of the economy; and among innumerable properties of life in the individual parts, produce that perfect cooperation as if one principle only actuated the whole.

When a person moves under the direction of the will, nothing can be more simple to our understanding, because we do not attempt to trace the links, far less to estimate the powers in the several parts influenced during this familiar action. But if there be the slightest diminution of sensibility of one nerve so that it shall not transmit sensation; or if there be any disturbance which retards in the least degree the transmission of the will along another appropriate nerve; if the muscle be benumbed, or have lost its irritability; if the action of the blood-vessels has been either diminished or increased beyond their ordinary course, either in the organs of sense, the brain, or nerves; we are appalled by the consequences. The impressions of things are not felt; the senses are unexercised; the limbs remain inactive; one half, or the whole, of the body is a load, as if there were a living being in a dead body—a body whose parts refuse their office, appearing dead though they are not so. The correspondence of their living qualities has alone been disturbed; the movement which results from the whole is stopped, and there is apparent death.

What confusion then must be engendered in the minds of those who would confound the phenomena of life, as presented in the entire framework of the body, with those separate qualities of life, which, residing in the several parts, must enter into combination for the motion of the whole! The next step of this unphilosophical manner of treating the subject, is to make the organization the source of the living property,—as if any combination of organs could produce life,—as if those organs could have motion without the distinct endowments of life in their separate parts,—as if

they cooperated mechanically, and not from the correspondence among their living properties. Those who thus reason mean to say, that parts are made so finely as to move of themselves, one part propelling another, and the motion of the whole producing life. It is quite clear that this confusion of ideas arises from contemplating the phenomena of the perfect animal, in which all intermediate influences are confounded. On the other hand we present this proposition.

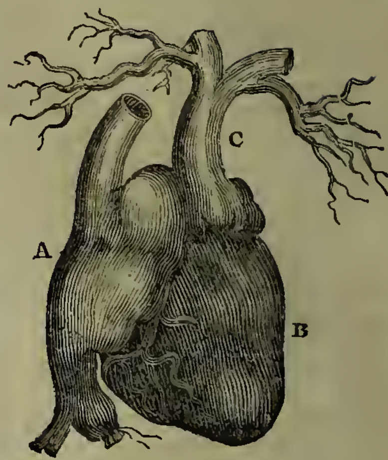
The several *simple* substances of a living body have each an endowment of life bestowed upon them. Let us take the obvious qualities, of sensibility—the power of transmission—and the power of motion; each of which is appropriate to a particular substance. When these qualities are put in relation, impressions may produce motion, and thus there are three distinct properties of life brought into operation. Where is the organization or construction here? Without those living endowments these parts would be inoperative, in whatever juxta-position placed. The mechanical construction of the body is one thing: and we are able to admire it, because it can be illustrated by comparison with our own contrivances; the combination of living properties is another and an entirely different thing.

We here reach the limit of philosophical inquiry. Hitherto all has been flattering to the pride of the creature; but we must now humbly acknowledge the inscrutable ways of the Creator; and ceasing to trace the origin of life, more than we do that of gravitation, we should be occupied in observing its laws, not in exploring its source.

We shall take an instance to illustrate the difference betwixt the mechanical connection of parts, and their relations through the living properties. And it will, at the same time, show how curiously the living properties and the mechanical properties are made to correspond with each other.

A stream of water is converted into a mechanical power; it fills a cistern, which is attached to a lever; the cistern descends by the weight of water; by its descent a valve is pushed open; the water escapes, and the cistern ascends, and remains so, till the stream flowing into it again, depresses it. Thus the regularity of the supply of water gives regularity of motion to the machine. Compare this with the heart.

Fig. 23.



We may describe the heart as consisting of two cavities, the one called the *Auricle*, and the other the *Ventricle*. The sinus A (*fig*.23) receives the blood returning by the veins, and gradually filling, like a cistern, it becomes so distended, that its muscular power is excited; it contracts, and delivers the blood with a sudden impetus into the second cavity, or the ventricle B; which, in its turn, excited by the distension, contracts, and propels the blood into the artery C. Here the action of the heart is accounted for, by its mechanical distension with the blood: and the regularity of its motions necessarily corresponds with the regularity of the supply. The distension produces action, and the propulsion of the blood from the cavity allows a momentary state of rest, until another volume of the blood excites another pulse.

But we have now to observe, that when this irritability or muscular power was bestowed upon the heart, it was directed by a law entirely different from the irritability, as possessed by other muscles. A property of alternate activity and rest was given to it, quite unlike the contractility of other parts; and accordingly when the heart is empty, when there is no distension of blood at all, the two cavities will continue their alternate action. Nay, if the heart be taken from the animal recently dead, it will continue to act in regular successive pulses, first the one cavity, and then the other, and so on successively for a long time, until the life be quite exhausted. The two cavities will thus continue in alternate action, as if they were employed in the office of propelling the

blood, when there is no blood contained within them. It is superfluous to observe, that no such thing could happen in the case of the cistern and lever, were the stream of water to cease running.

Thus we distinguish two things quite different, a mechanical or hydraulic provision, by which these little cisterns, the auricle and ventricle, shall be regularly supplied, and alternately filled and emptied—and the property of contraction in the heart; not a mere property of contraction from irritation, as in the other muscles, but a property far more admirable, since the irritability or power of contraction of the part, is ordered with a reference to its office—that it shall contract and relax in regular and rapid succession, and continue its office unweariedly through a long life. The living property of the heart exhibits a variety adapted to its office, and a correspondence still more admirable than the mechanical relation.

We are thus particular in distinguishing the mechanical adaptation of parts, from the cooperation of the vital influences residing in the several parts; for there are many who will take the illustration from mechanics, and stop their inquiry there, and who entertain a confused notion of the dependance of the life of the body on its mechanism.

Another mistake, which some philosophical inquirers entertain, is to fancy that the principle of life is of a galvanic nature. There is indeed an unwillingness in men to acknowledge that their powers of reason are exhausted, and that they have arrived at an ultimate stage; they would fain set up some contrivance to hide the humiliating truth. Whatever notions have prevailed in the schools at different epochs, of heat, electricity, or galvanism, we find an attempt to explain the phenomena of life by an application of the powers, with which they have been successful in their physical inquiries. Experiments without reason are equally delusive with hypotheses; those who will not give themselves the labour of thought, desire to witness striking phenomena; wonder-struck, they believe that they are engaged in experimental investigation, when their state of mind is little better than idle amazement. A calf's head is made to yawn, or a man cut down from the gallows to move like a figure of cards pulled with strings; the jaws move, and the eyes roll, and this is done by conveying the galvanic shock tot he nerves; here it is supposed that nothing less than the principle of life itself can work such wonders, and that galvanism is this principle.

Putting aside the circumstance already stated, of life exhibiting totally different phenomena in union with different parts, is there any point of resemblance between galvanism and life? Does tying the nerve stop the influence of galvanism, as it does the influence of life? Does galvanism course along a cord when it is surrounded by matter in contact with it of the same nature? Can life pass out of one body into another, like heat, or electricity, or galvanism? Can *they* be contained by a thin membrane? Does life pass equally through all the parts of a moist animal body as one uniform influence, like galvanism?

In no circumstance is there a resemblance, and the whole phenomena resulting from galvanism transmitted through an animal apparently dead, are fairly to be attributed to its being a high stimulus conveyed through the moist animal body, and exciting the powers which remain insulated in the several parts; and in exciting those forces, far from renewing them, it exhausts them altogether.

The uses made of galvanism in the explanation of the living phenomena, should make sensible men very cautious how they carry the legitimate inductions of chemical science into another department. They will not submit to call the irritability or contractility of a muscle an endowment of life, but seek to explain it by organization. They employ the microscope; they find the ultimate fibre to be some thousandth part of an inch in breadth; they see plicæ or folds; they imagine them to be cells into which the fibres are divided; they furnish these cells with two different gases, and explode them by some galvanic influence of the nerves; and the explosion by dilating the cells in one direction, causes the contraction in another. This is the theory of muscular action at the period of the discovery of the gases; and some such idle hypothesis, supposed applicable to the laws of life, accompanies every considerable improvement in chemistry.

In the most modern and the most popular French work on Physiology, by Mons. Richerand, he says, "What appears to me by much the most ingenious opinion, and which carries with it the greatest probability, is that which supposes the contraction of the muscle

to depend on the combination of hydrogen, carbon and azote, and other combustible substances which exist in the fleshy fibre, with the oxygen conveyed to them through the arteries." But he adds, 'as if he had perfected the theory,' "it is also necessary to suppose, that a nervous fluid is directed through the muscle to determine the decomposition, as the electric spark forms water out of two gases."

Such is the chemical theory of muscular motion; it betrays an entire misunderstanding of the phenomena of muscular motion, and of the beautiful provision in every muscle for its appropriate office. The muscles, which are subservient to the organs of sense, differ in their operations altogether from the voluntary muscles of the limbs. The hollow muscles, as they are termed, those which carry down the food, and which carry round the blood in circulation, vary in their time and manner of acting according to their offices; but what conception can he have of such adjustment of powers, who is entertaining himself with a theory, that supposes a sudden explosion to take place in the fibres of the muscle at their time of action? Inductive reasoning, which has carried men to the highest acquirements in physical science, is here laid aside; conjectures totally inconsistent with the phenomena of life are employed in its stead; and the useful philosopher becomes a very indifferent physiologist.

Chapter III.

Of Sensibility.

Under this head are comprehended, not any sentiment or feeling of the mind, but the sensations of the body.

We form our notions of sensibility from that of the skin; and it is no doubt necessary that we should do so. It is in constant communication with things around us, and affected by their qualities; it affords us information, which corrects the notions received from the other organs of sense, and it excites our attention to preserve our bodies from injury. We are so familiar with the painful effects of injuries upon the surface, that there is nobody who does not imagine that the deeper the injury, the more dreadful the pain. But, on the contrary, it is a well-established fact, that to such irritants as would give the skin pain, the internal parts are totally insensible. And it is equally certain, that though the nerves, the instruments of sensation, are incapable of producing any perception without the brain, yet the brain itself, the part which is the seat of intellect, and to which every impression must be referred before we become conscious of it, is itself as insensible as leather. These considerations show us that sensibility to pain, is not a necessary result of life, and they naturally lead to the inquiry for what purpose is sensibility bestowed, and how is it distributed in the body?

We have first to show that the skin has sensibilities exactly suited to the functions it has to perform. Science no doubt informs us, that warmth and cold are only relative degrees of heat; to the skin they are distinct sensations, and excite in different ways both the mind and the bodily functions. Cold braces and animates to exertion, whilst the warmth which is pleasant to us, is genial to all the operations of the animal economy. Their alternations are the most constant sources of our enjoyment, and at the same time conduce to exertion and to health. All this, however, belongs to the skin exclusively; parts internal, although peculiarly sensible to their proper stimulus, give no indication of sensibility to heat; if there be internal sensations of heat, they are morbid and deceptious. Molten lead would produce pain and death being poured into the interior of the body, but the sensation of burning is a property of the surface only. It is the excess of that particular sensation, which is calculated, like the other endowments of the skin, to suit the medium in which we live, and to force us to the regulation of the temperature necessary to preserve life.

Touch, or the sensibility to bodies pressed upon the skin, is likewise a distinct and appropriate sense. The sensibility of the skin to pricking, cutting, or tearing, is also in curious contrast with the sensibility of the solid internal textures, as bone, cartilage, and ligament. We have arrived at the full comprehension of this subject very slowly. Disagreeable experiments have been made, but the following is as interesting as it was innocently performed. A man who had his finger torn off, so as to hang by the tendon only, came to a pupil of Dr. Hunter. "I shall now see," said the surgeon, "whether this man has any sensibility in

his tendon.' He laid a cord along the finger, and, blindfolding the patient, cut across the tendon. "Tell me," he asked, "what I have cut across?" "Why, you have cut across the cord, to be sure," was the answer. By such experiments it became very manifest, that bone, gristle, and ligament, were insensible to pricking, cutting, and burning. Were they, therefore, insensible? The reader will answer—Surely, it is a matter proved. But before we finally decide, let us take this into consideration,—that the sensibilities of the body differ in kind as well as in degree; and every part has its peculiar kind, as well as its degree; and every part has its kind of sensibility with reference to its function, and also with reference to its protection from violence. If the membranes between the bones of our great joints, or the cords which knit the bones, were sensible in the same manner and degree with the skin, we should be incapable of motion, and screwed to our seats; as the man appears to be who has a violent attack of acute rheumatism.

But although these bones and cartilages, or gristles, and ligaments, be not sensible as the skin, or the surface of the eye, they possess that which is suited to their condition, which permits their free use, and yet limits that too free exercise which would be injurious to their textures, or raise inflammation in them. The ligaments and tendons, then, which are insensible to pricking, cutting, and burning, are sensible, nevertheless, to stretching and tearing! It is remarkable that such men as Dr. Hunter and Haller, the luminaries of their science, should have held the opinion that the bone and the membrane which covers it (the *periosteum*), the gristles or cartilages, the ligaments of joints, and the tendons of muscles were insensible parts, and yet be in daily attendance on those who suffer the pain of a sprained ankle, where there are no parts to suffer but those enumerated, and where the pain, excessive in degree, was felt in the instant of the sprain. These considerations explain to us that pain is the safeguard of the body. This capacity of conveying painful impressions to the mind is not given superfluously to all parts; on the contrary the safe exercise and the enjoyment of every part is permitted without alloy, and only the excess restrained.

This subject is finely illustrated by the apparent insensibility of the heart. The observation of the admirable Harvey, the discoverer of the circulation of the blood, is to this effect. A noble youth of the family of Montgomery, from a fall and consequent abscess on the side of the chest, had the interior marvellously exposed, so that after his cure, on his return from his travels, the heart and lungs were still visible and could be handled; which when it was communicated to Charles I., he expressed a desire that Harvey should be permitted to see the youth and examine his heart. "When," says Harvey, "I had paid my respects to this young nobleman, and conveyed to him the king's request, he made no concealment, but exposed the left side of his breast, when I saw a cavity into which I could introduce my fingers and thumb; astonished with the novelty, again and again I explored the wound, and first marvelling at the extraordinary nature of the cure, I set about the examination of the heart. Taking it in one hand and placing the finger of the other on the pulse at the wrist, I satisfied myself that it was indeed the heart which I grasped. I then brought him to the king that he might behold and touch so extraordinary a thing, and that he might perceive, as I did, that unless when we touched the outer skin, or when he saw our fingers in the cavity, this young nobleman knew not that we touched the heart!" Other observations confirm this great authority, and the heart is declared insensible. And yet the opinions of mankind must not be lightly condemned. Not only does every emotion of the mind affect the heart, but every change in the condition of the body is attended with a corresponding change in the heart: motion during health the influence of disease—every passing thought will influence it. Here is the distinction manifested. The sensibility of the skin is for a purpose, and so is the sensibility of the heart. Whilst the skin informs us of the qualities of the external world and guards us against injury from without, the heart, insensible to touch, is yet alive to every variation in the constitutional powers, and subject to change from every internal influence.

There is in the several organs of the body, as it were, a distinct life; that is, they possess sensibility, the grand endowment of life, necessary to their condition and adapted to their appropriate stimulus. The impressions made upon them will sometimes rouse them into

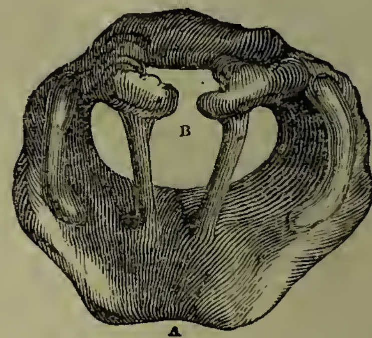
activity, or call muscles into action which are necessary to their functions or for their protection; and this oftentimes without reference to the mind at all, and consequently without our consciousness.

Perhaps we have the most agreeable example of this in the eye. That organ has been selected, in the Preliminary Discourse of the Objects and Pleasures of Science, as showing how mechanical advantage is taken in the arrangement of the muscles to produce velocity of movement in guarding the eye. But this fine mechanism would be lost if the excitement depended on our will,—if there were not a sensibility appropriate to the action, and an influence quicker than thought. It is not by feeling the pain of the offensive body, or by estimating its dangers and acting on the conviction, that we close the eye to avoid injuries. This would be an operation all too slow for the intended purpose; and therefore the muscles, possessing these extraordinary provisions, are put in relation with a sensibility more admirable still. So when a light foreign body touches the eyelashes, they give alarm, and cause a motion both of the eyelids and eyeball quicker than thought. The eyelashes, seated on the tender extremities of sensitive nerves, preserve the eye in two ways—by guarding its interior from the lateral light, and by exciting the motion of the eyelids, even before the offensive body can touch the eye's surface.

We may take another illustration to show how sensibility, one of the endowments of the living part, is adapted to the mechanical organization, and with an appropriation more admirable than the mechanism. When we speak of the sensibility of the skin, it is still possible to misconceive its nature, and to suppose it accident merely; but in the instance to be adduced, the sensibility is different, and it is put in connection with a hundred muscles; without this high and peculiar sensibility, and its multiplied relations to muscles, independent of volition, the mechanism we are about to describe would be quite useless.

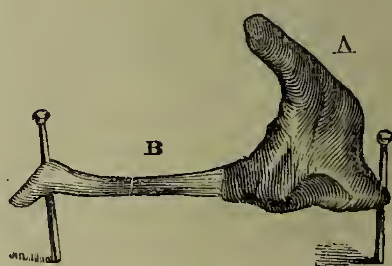
The top of the windpipe is called the *larynx*, and consists of five elastic cartilages. These do not merely keep the sides of the windpipe apart, and the passage for the breath free, but they perform offices important to the economy both of body and mind; they are an essential part of the instrument of voice; they, at the same time, guard the lungs from injury.

Fig. 24.



The *thyroid* cartilage is the largest of the cartilages of the larynx, it is that we feel projecting on the fore part of the throat, called the *pomum adami*, (A.) It is a protection to the fine apparatus behind it, and indeed this is the reason of its name, (*scutiform*, like a shield.) Within the thyroid stand the *arytænoid* cartilages, (B.) This cartilage is of an

Fig. 25.



irregular triangular form. It is socketed or articulated on the cartilage below, and is perfectly movable. To the corner which projects forwards the ligament (B) is fixed, and to its other sides five little muscles are attached; these muscles, by moving the cartilage, draw and vary the position of the ligament. It is these cartilages and this ligament, which, vibrating in the stream of air, give the tremor, and vocalize the breath; the tones so produced are articulated in speech.

This is a subject far from being exhausted in our philosophical works, and may call for observation afterwards; but at present we may look on these ligaments, not as the *cordæ vocales*, but

in another of their offices—forming the slit which opens and shuts in breathing, for the protection of the lungs. But here it is pertinent to remark, that in the structure of an animal body one organ is made subservient to several functions, without interference in the performance of any of them. This is especially true of the larynx. It is one of those uses only, and the least important, that we have at present to observe.

The ligaments being invested with the lining coat, or membrane of the wind-pipe, draw it into the form of a slit like the till of a shop counter, and this is the chink of the glottis (*rima glottidis.*) This slit opens and closes with every inspiration, moving as we see the nostrils do in breathing. But the most admirable thing of all is the acute sensibility given to this part, and to no other, so that the lightest husk, or seed, or smallest fly, drawn in with the breath, and touching the margin of the chink, is caught there by the rapid action of the muscles and consequent closing of the aperture. Now were the provision for the protection of the lungs to be only thus far perfect, there would be an effectual means of preventing the intrusion of foreign matter into the delicate cells of the lungs, but not for its expulsion from the entrance which it had reached. Accordingly, although the sensibility of the glottis is put in operation with the shutting of the chink, it also animates another class of muscles; viz. all those which, seated on the chest, compress it, and force out the air in coughing; and these combining in one powerful and simultaneous effort, whilst the glottis is closed, overcome that constriction, and propel the breath through the contracted pipe with an explosive force, which brushes off the offending body. There is one thing more, necessary to this most important though familiar action;—the lungs are never empty of air; in breathing we do not fully expel the air; if we did, there would be a period of danger occurring 17 times in a minute; for in the first part of each inspiration something might be drawn into the wind-pipe, which would suffocate. But by this provision of air retained in the lungs more than necessary to respiration, and which it is possible to expel by a more forcible expiration, there is always a possibility of coughing and expelling the offensive thing at any point of time in the act of inspiration.

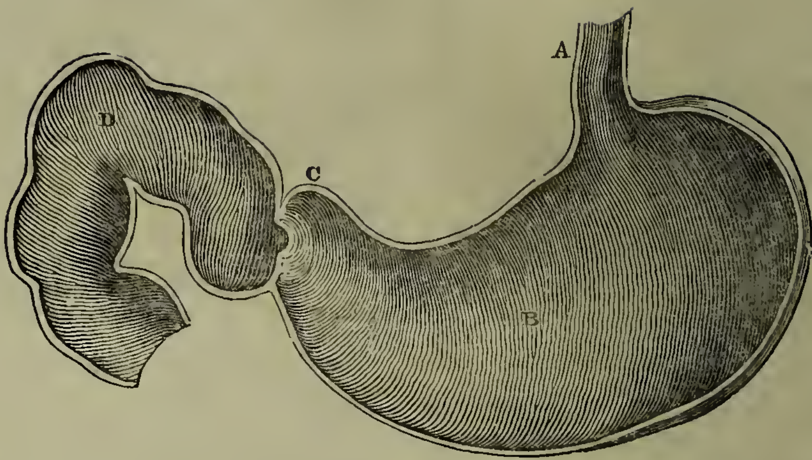
The sensibility seated in a spot of the throat so beneficently, does not extend into the wind-pipe; for we cannot more admire the perfect adaptation of this living property, than the circumstance of its never being bestowed in a superfluous degree, nór extended where it is not absolutely required. Just as the sensibility of the skin protects the parts beneath, so in the same manner does the sensibility of the top of the wind-pipe protect all the interior of the tube, and the lungs themselves, without the necessity of this property of irritability extending through the whole continuous surface.

The simple act of sneezing affords a very curious instance of the mutual adaptation of muscular activity and the governing sensibility. The sensation which gives rise to this convulsive act, is seated in the membrane of the interior of the nostrils, and we are not surprised with the difference of sensation from that in the throat which excites coughing. But is it not a very curious thing to find some twenty muscles thrown out of the action excited by irritation of the nose; and as many excited which were not in the class of those influenced in coughing; and for the very obvious purpose of shutting the passage by the mouth, or at least forcibly driving the air through the nostrils? No act of the will could so successfully propel the air through the nose in such a way as to remove the offensive and irritating particles from the membrane of the nose, and clear those passages.

These last examples of an appropriate sensibility might introduce us to an acquaintance with those internal sensibilities which govern the actions of parts quite removed from the influence of the will; but the description of them may be deemed unnecessary. We shall just hint at the guard which nature has placed on the lower orifice of the stomach, to check the passage which the appetites of hunger and thirst may have given at the upper orifice (A) to aliments, not easy of digestion. This lower orifice (C) is encircled with a muscular ring; the ring is in the keeping of a watchful guard. If we are employing the language of metaphor, it is of ancient use. The Greeks called this orifice *pylorus*, which signifies a porter,*

* The upper orifice was called by them *œsophagus*, as it were the *purveyor*, from two words signifying to bring food.

Fig. 26.



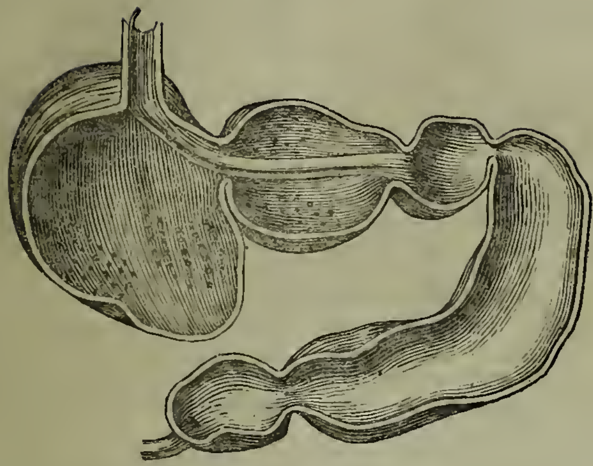
and his office is this.—When the stomach has received the food, it lies towards the left extremity, or is slightly agitated there. When the digestive process is accomplished, the stomach urges the food towards the lower orifice. If the matter be bland and natural it passes, and no sensation is experienced. But if crude and undigested matter be presented, opposition is offered to its passage, and a contention is begun which happily terminates in the food being thrown again to the left extremity of the stomach, to be submitted to a more perfect operation of the digestive powers seated there. It is during this unnatural retrograde movement of the food, that men are made sensible of having a stomach. Yet the sensations, how unpleasant soever, are not to be regarded as a punishment, but rather as a call on reason to aid the instinctive powers, and to guard against disease, by preventing impure matter from being admitted into the portion of the intestinal canal, which absorbs, and would thus carry those impurities into the blood to engender disease.

Such are a few examples of the variety in the sensibilities of the animal frame; guarding us against external influences when they would threaten destruction to the framework, and adjusting the operations of internal parts too complicated and too remotely situated for the superintendence of reason.

Medical authors, without being empirics, do, notwithstanding, take great advantage of our ignorance. We can all of us take warning from the sensations experienced in the process of digestion, and there can be no harm in giving every man a confidence in the sensibility of his stomach, and in its indications of healthy or disturbed functions. We have the best proof of what we wish to inculcate in the action of the ruminating stomach. A cow swallows the gross herbage, and fills its large first stomach. When it chews the cud, the stomach, by its action, rolls up the grass into distinct pellets, or balls, with as much regard to the office of its being rejected into the mouth, as we do in masticating for swallowing. When the ball is brought into the mouth and chewed, it is again swallowed; but in descending into the lower part of the gullet a muscle draws close the aperture by which it passed into the large stomach in the first instance, and it is now ushered into a second stomach, and so successively onwards to that stomach in which the digestion is performed. The curious muscular apparatus by which this is accomplished needs not be described; but surely the sensibility which directs it, which, kept apart altogether from the will, is yet, in its results, so like the operations of reason, presents a subject of just admiration.

The elastic structure of the camel's foot; the provision around its eyes for ridding them of offensive particles; the power of closing its nostrils against the clouds of sand; and its endurance of fatigue—would not enable it to pass the desert, unless there were provisions for the lodgment of water in its stomach, and unless this apparatus were animated by peculiar sensibilities; for there are muscles to retain the fluid in the cells of

Fig. 27.



its stomach, only permitting it to ooze out according to the necessities of the animal; and there is a muscle, represented in the *fig.* above, which pulls up the one or the other of the orifices of the different stomachs to receive the food from the lower end of the gullet, according to its condition, whether to be deposited merely as in a store, or to be submitted to the operation of digestion.

The surprising thing in all this, is not so much the mechanical provision as the governing sensibility. What, for example, should in the first place impel the grosser food, when collected, into the first stomach? What should, in the next place, and after rumination and mastication in the mouth, carry it into the third stomach; since water is carried into neither of these, but into the cells of the second stomach?

Yet, after all, this only brings us back to a sense of the operations of our own bodies. The act of swallowing, the propulsion of the food into the gullet, and the temporary closing of the windpipe at such a time, is just as surprising. This latter operation is never deranged but by the interference of the will. If the individual attempts to speak, that is, to govern these parts by the will, when they should be left to these instinctive operations; or if terror, or some such mental excitement, prevail at the moment of swallowing, then the morsel may stick in the throat.

All this shows how perfect the operations of nature are, and how well it is provided that the vital motions should be withdrawn from the control of reason, and even of volition, and subjected to a more uniform and certain law.

But the point to which we would carry the reader is this, that though there are the proper sensibilities of the body, with reference to perception or consciousness, yet there are others no less curious, which control the internal operations of the economy; and that the mechanical provisions are but a type of what is promised to him who will look into the sensibilities of the body for the proof of power and contrivance.

Now the human stomach, though not so complicated in its apparatus of macerating and digesting vats, is possessed of a no less wonderful degree of governing sensibility, which may be trusted as surely as the most skilful physiologist.

We are told that we must not drink at meals, lest the fluid interfere with the operation of digestion; of this there need be no apprehension. The stomach separates and lets off with the most curious skill, all superfluous fluid through its orifice, while it retains the matter fit for digestion. It retains it in its left extremity, permitting the fluid to pass into the intestines, there to supply the other wants of the system no less important than the digestion. The veterinary professor Coleman, ascertained that a pail of water passed through the stomach and intestines of a horse, at the rate of ten feet in the minute, until it reached the cæcum. Drinking at a stated period after meals, say an hour, is at variance with both appetite and reason. The digestion is then effectually interfered with; for what was solid has become a fluid, (the *chyme.*

This fluid is already in part assimilated; it has undergone the first of those changes which fit it ultimately to be the living blood; and the drink mixing with this chyme in the inferior extremity of the stomach, or first intestine, must produce disturbance, and interrupt the work of assimilation.

Looking in this manner upon the very extraordinary properties of the stomach, we perceive how natural it was for physicians to give a name to the sensibility of which we have been speaking. The *Archeus* of Vanhelmont, the *Anima* of Stahl, were the terms used to designate this nature, principle, or faculty, subordinate to, and distinct from perception;—a notion entertained, and more or less distinctly hinted at, by philosophers from Pythagoras to John Hunter.

A modern philosopher,* of whom, in this instance, it would be difficult to say whether he be serious or playful, with some plausibility, however, asserts that it might be possible to carry on the business of life without pain. If animals can be free from it an hour, they might enjoy a perpetual exemption from it. Animals might be constantly in a state of enjoyment; instead of pain, they might feel a diminution of pleasure, and might thus be prompted to seek that which is necessary to their existence.

In the lower creatures, governed by instinct, there may be, for ought we know, some such condition of existence. But the complexity and delicacy of the human frame is necessary for sustaining those powers or attributes which are in correspondence with superior intelligence; since they are not in relation to the mind alone, but intermediate between it and the external material world. Grant that vision is necessary to the developement of thought, the organ of it must be formed with relation to light. Speech, so necessary to the developement of the reasoning faculties, implies a complex and exceedingly delicate organ, to play on the atmosphere around us. It is not to the mind, that the various organizations are wanted, but to its condition in relation to a material world.

The necessity of this delicate structure being admitted, it must be preserved by the modifications of sensibility, which shall either instinctively protect the parts, or rouse us into powerful and instantaneous activity. Could the eye guard itself, unless it possessed sensibility greater than the skin? Could it guard itself, unless this sensibility were in consent with an apparatus which acted as quick as thought? Could we, by the mere influence of pleasure, or by any cessation or variation of pleasurable feelings, be made alive to those injuries which might reach the lungs by substances being carried in with the air we breathe? Is there anything but the sense which gives rise to the apprehension of suffocation, that would produce the instant and sudden effort which could guard the throat from the intrusion of what was offensive or injurious. Pleasure is at the best a poor motive to exertion, and rather induces to languor and indulgence, and at length indifference. To say that animals might be continually in a state of enjoyment, and that when urged by the necessities of nature, such as thirst, hunger, and weariness, they might only feel a diminution of pleasure, is not only to alter man's nature, but external nature also; for, whilst there are earth, rocks, woods, and water for our theatre of existence, the textures of our bodies must be exposed to injuries, from which they can only be protected by a sensibility adapted to each part, and capable of rousing us to the most animated exertions. Take away pain, and take also away the material world, by which we are continually threatened with injury, and what, after all, is this, but imagining a future state of existence, instead of that in which mind and matter are combined? If all were smooth in our path, if there were neither rugged places nor accidental opposition, whence should we derive those affections of our minds, which we call enterprise, fortitude, and patience?

Independent of pain, which protects us more powerfully than a shield, there is inherent in us, and for a similar purpose, an innate horror of death. "And what thinkest thou (said Socrates to Aristodemus) of this continual love of life, this dread of dissolution, which takes possession of us from the moment that we are conscious of existence?" "I think of it, (answered he,) as the means employed by the same great and wise artist, deliberately determined to preserve what he has made."

The reader will no doubt here observe the distinction. We have experience of pain from injuries, and learn to

* Hume.

avoid them; but we can have no experience of death, and therefore the Author of our being has implanted in us an innate horror at dissolution; and we may see this principle extended through the whole of animated nature. Where it is possible to be taught by experience, we are left to profit by it, but where we can have none, feelings are engendered without it. And this is all that was necessary to show how the life is guarded; sometimes by mechanical strength, as in the skull; sometimes by acute sensation, as in the skin and in the eye; sometimes by innate affections of the mind, as in the horror of death, which will prevail as the voice of nature, when we can no longer profit by experience.

But the highest proof of benevolence is this, that we have the chiefest source of happiness in ourselves. Every creature has pleasure in the mere exercise of his body, as well as in the languor and repose that follow exertion; but these conditions are so balanced, that we are impelled to change, and every change is an additional source of enjoyment. What is apparent in the body, is true of the mind also. The great source of happiness is to be found in the exercise of talents, and perhaps the greatest of all is when the ingenuity of the mind is exercised in the dexterous employment of the hands. Idle men do not know what is meant here; but nature has implanted in us this stimulus to exertion, that she has given to the ingenious artist—the man who invents, and with his hands creates, a source of delight, perhaps greater, certainly more uninterrupted, than belongs to the possession of higher intellectual powers, and far beyond any that falls to the lot of the minion of fortune.

We believe that every thinking person may have wherewithal in his own sphere to tutor him, and bring him to the temper of mind and belief which we would inculcate. Yet there is something peculiarly appropriate in the study of our own bodies. In chemistry we are so much the agents as to forget the law, and the law itself seems at least to intermit. But in the changes wrought in the animal frame, the directing power is uniform in its influence, and holds all in harmony of action.

We now learn without difficulty and without mystery, what is meant by organic and animal sensibility. The first is that condition of the living organ, which makes it sensible of an impression, on which it reacts and performs its functions. It appears from what has preceded, that this sensibility may cause the blowing of a flower, or the motion of a heart. The animal sensibility is indeed an improper term, because it would seem to imply that its opposite, organic sensibility, was not also animal; but it means that impression which is referred to the sensorium; where, (when action is excited,) perception and the effort of the will are intermediate agents between the sensation and the action or motion.

We may sum up the inquiry into sensibility and motion thus:—

1. The peculiar distinction of a living animal is, that its minute particles are undergoing a continual change or revolution under the influence of life. Philosophers have applied no term to these motions.

2. An organ possessed of an appropriate muscular texture, and of sensibility in accordance with the moving instrument, as the heart, or the stomach, has the power of action without reference to the mind. The term *automatic*, sometimes given to those motions, conveys a wrong idea of the source of motion, as if, instead of being a living power, it were consequent upon some elastic or mechanical property.

3. There are sensibilities bestowed on certain organs, and holding a control over a number of muscles, which combine them in action in a manner greatly resembling the influence of the mind upon the body, yet independent of the mind; as the sensibility which combines the muscles in breathing.

4. In the last instance a large class of muscles were combined without volition. But the whole animal fabric may be so employed; as in the instinctive operations of animals, where there is an impulse to certain actions not accompanied by intelligence.

5. A motive must exist before there are voluntary actions, and hence philosophers have supposed that there can be nothing but instinctive actions in a new-born child. But we must distinguish here what are perfect at first, and what are imperfect and irregular, and become perfect by use and the direction of the will. The act of swallowing is perfect from the beginning. The motions of the legs and arms, and the sounds of the voice are irregular and weak, and imperfectly directed. It is the latter

which improve with the mind. From not knowing the internal structure, and the arrangement of the nerves, philosophers, as Hartley, supposed, that an instinctive motion, such as swallowing, may become a voluntary act. Volition in the act of swallowing, consists merely in putting the morsel within the instinctive grasp of the fauces, when a series of involuntary actions commence, over which we have no more control in mature age, than in the earliest infancy. Swallowing is not a voluntary action, and the thrusting the morsel back with the tongue, is like putting the cup to the lip. It is the preparation for the act of swallowing that is voluntary, but over the act itself, we have no control.

It is an error to suppose that all muscular actions are, in the first instance, involuntary, and that over some of them we acquire a voluntary power. The power of volition over the muscles of the body, is provided for by appropriate nerves, and no apparatus which is not supplied with that particular class of nerves, can ever, by any exercise or study, become subject to volition. A child's face has a great deal of motion in it, very diverting from its resemblance to expression, before there can be any real motive to the action. It will crow, and make strange sounds, before there is an attempt at speech. But this gradual developement of intelligence and acquisition of power ought not to be called the will attaining influence over involuntary muscles; since, in fact, the apparatus of nerves and muscles is prepared and waits for the direction of the mind with so perfect a readiness, as to fall into action and just combination, before that condition, or affection of the mind which should precede the action, takes place. A child smiles before any thing incongruous can enter the mind, before even pleasure can be supposed a condition of the mind. Indeed, the smile on an infant's face is first perceived in sleep.

6. All the motions enumerated above, are spontaneous motions belonging to the internal economy; but the external relations of the animal, the necessity of escaping from injury, or warding off violence, require a sensibility suited to those outward impressions,and an activity consequent on volition. Nothing less than perceptions of the mind, and voluntary acts, suited to a thousand circumstances of relation, could preserve the higher classes of animals, and man above all others, from destruction.

All these provisions proceed from an arrangement of nerves and muscles. The mechanical adjustment of the muscles and tendons, is perfect according to the principles of mechanics. The muscles themselves possess a different property; they are irritable parts; motion originates in them. This living property of contraction is admirably suited, in each particular muscle, to the office it has to perform. In some it is suitable that the muscles should act as rapidly as the bowstring on the arrow; in others the action is slow and regular; in others it is irregular, and after long intervals, according as the functions to which they are subservient require. The motions of the limbs, the motions of the eye, those of the heart and arteries, stomach and bowels, are all different. This appropriation of action is not in the muscles themselves, but as they stand in relation to the nervous system, and the sensibilities which impel them.

We hope, then, by the course we have taken, that we have carried the reader to a higher sense of the perfection of the animal structure. We first drew him to observe provisions in the strengthening of the bones, the adjustment of their extremities to the joints, the course of the tendons, and other such mechanical appliances, proving to him the existence of intention in the formation of the solid fabric of the body. We have then explained how that motion is produced which was at all times familiar to him, but even the immediate causes of which he did not comprehend. We have, in the last place, shown him that under the term life he has a still more admirable subject of contemplation in the adjustment of those living properties; in the sensibilities differing not so much in degree as in kind; and in their appropriation, both to the operations of the internal economy, and to the relations external, and necessary to safety.

It is not possible to contemplate these things without having the full proof before us of the power of the Creator in forming and sustaining the animal body. As a man with *gutta serena* may turn his eyes to the sun, and feel no influence of light; so may the understanding be blind to these proofs; and we may say, with the celebrated

Dr. Hunter, that he who can contemplate them without enthusiasm, must labour under a dead palsy in some part of his mind, and we must pity him as unfortunate.

Chapter IV.

Of the Changes in the Material of the Animal Body during Life.

We have seen the motions performed in the animal body through the actions of the muscles, and the play of the mechanical parts, and we have had occasion to reflect on the action of the heart, and the motion of the blood in the circulation; but these are as nothing, compared with the interest of our present subject—the changes going forward in the solid material of the frame. Is it not surprising that the individual who retains every peculiarity of body and of mind, whose features, whose gait and mode of action, whose voice, gestures, and complexion we are ready to attest as the very proof of personality, should in the course of a few days change every particle of his solid fabric?—that he whom we suppose we saw, is, as far as his body is concerned, a perfectly different person from him we now see? That the fluids may change we are ready to allow, but that the solids are thus ever shifting seems at first improbable. And yet, if there be any thing firmly established in physiology, if there be truth in the science at all, this fact is incontrovertible.

There is nothing like this in inanimate nature. It is beautiful to see the shooting of a crystal;—to note, first, the formation of integrant particles from their elements in solution, and these, assuming a regular form under the influence of attraction or crystalline polarity, producing a determinate shape; but the form is permanent. In the different processes of elective attraction, and in fermentation, we perceive a commotion, but in a little time the products are formed, and the particles are at rest. There is in these instances nothing like the revolutions of the living animal substance, where the material is alternately arranged and decomposed. The end of this is, that the machinery of the body is ever new, and possesses a property within itself of mending that which was broken, of throwing off that which was useless, and of building up that which was insecure and weak; of repelling disease, or of controlling it, and substituting what is healthful, for that which is morbid. The whole animal machinery we have seen to be a thing fragile and exposed to injury; without this continual change of material, and this new modelling of that material, our lives would be more precarious; the texture of our bodies would be spoiled like some fine piece of mechanism which had stopped, and no workman would have science sufficient to reconstruct it. But by this process, the minute particles of the body die successively; not as in the final death of the whole body, but part by part is deprived of its vitality, and taken away into the general circulation, whilst new parts are endowed with the property of life, and are built up in their place. By this revolution, we see nature, instead of having to establish a new mode of action for every casualty, heals all wounds, unites all broken bones, throws off all morbid parts by the continuance of its usual operations; and the surgeon who is modest in his calling, has nothing to do but to watch, lest ignorance or prejudice interfere with the process of nature. This property of the living body to restore itself when deranged, or to heal itself when broken or torn, is an action which so frequently assumes the appearance of reason, as if it were adapting itself to the particular occasion, that even the last great luminary in this science, Mr. John Hunter, speaks of parts of the body, as "conscious of their imperfection," and "acting from the stimulus of necessity," thus giving the properties of mind to the body, as the only explanation of phenomena so wonderful.

We make a moderate assumption, when we declare these changes to be under the guidance of the living principle. In a seed, or a nut, or an egg, we know that there is life, and from the length of time that these bodies will remain without change, we are forced to acknowledge that this life is stationary or dormant, and limited to the counteraction of putrefaction or chemical decomposition; but no sooner does this principle become active, than a series of intestinal or internal changes are commenced, which are regularly progressive, without a moment's interruption, while life continues.

That principle which may continue an indefinite number of days, months, or years, producing no change in all this

time, begins at once to exhibit its influence, builds up the individual body, regulates the actions of secretion and absorption; and, by its operation upon the material of the frame, stamps it with external marks of infancy, maturity, and age.

But let us examine the proofs of this universal change in the material of the body. It is not very long since a bone was supposed to be a concrete juice, and that the liquid parts were converted into solids, as we see mortar or Paris plaster from fluid assuming a solid form. But the anatomist began to observe, that the bones were porous; that these pores admitted membranes and vessels; and some went so far before their brethren, as to assert that they saw arteries, veins, lymphatics, and nerves going into the bone; in short, the opinion gradually grew stronger, that they were living parts, and subject to all the changes to which the softer parts of the living body were liable. An accident gave admirable proof of this. It was found that the bones of pigs, fed with the refuse of the dyer's vats, in which madder was contained, became tinged of a beautiful red colour. It was this fact which ingenious physiologists made use of, and which enabled them to demonstrate the rapidity with which the old bone was carried away, and new bone substituted. The physiologist observed, that if he threw a bone into the fire, what is called the animal part was burned and dissipated, but there remained, imperishable by this process, a mass of earth, which proved to be the phosphate of lime. He thought of varying his experiment, and put the bone into acid, which dissolved that phosphate of lime, and left the bone to all outward appearance as before. It had its form, its membranes, its vessels, but when pressed it proved to be soft and pliant; the phosphate of lime having been dissolved and extracted, it was no longer capable of the office of a bone, to bear the weight and motions of the body. When the experiments with madder were resumed, it appeared, that when this earth of bone was about to be secreted from the circulating vessels, and deposited in the membranes of the bone, it met with the colouring particles of the madder in the blood; and, as the chemist would explain, the madder and the phosphate of lime were precipitated, and filled all the interstices of the membranes and vessels. We shall not stop here to inquire into the admirable manner in which this hardening material of bone is deposited for the purposes of strength. It is only the change upon the material which we have now to contemplate.

If this earth of bone, so coloured, had been deposited for a permanency, and built into these cells and crevices, like brick and mortar, the colour would remain; but, however deeply the bones of an animal may be tinged in this manner, the colour is not permanent, unless the animal continue to be fed with the madder. If its food be pure of the madder, even for a few weeks, and if after this the animal be killed, its bones are white, that is to say, the old particles of phosphate of lime are carried away by absorption, and with them the colouring material; and that newer bone which is deposited by the arteries is untinged and pure, having no colouring material to attract.

It is unnecessary to follow out those curious experiments by which the physiologist has shown the rapidity of the formation of a new bone around the broken end of an old one, and the deep tinge such new bone takes, compared with the fainter colour of that which had been perfect, previous to the feeding with madder; the manner in which, by feeding the animal alternately with madder and without it, he contrives to exhibit different coloured layers in the growing bone. It is sufficient for our purpose, to know that the densest part of the animal frame is subject to change, like the most delicate texture of the body, and that the only means of arresting the motion, is to deprive it of life: if a part of a bone be killed by the application of a cautery, that moment it becomes permanent, and is subject to no change, whilst all the parts around it are undergoing their revolutions.

The bones of the legs and thighs, which suffer the fatigue of motion, and which support the weight of the body, without diminishing in their length, or altering in the slightest measurable degree their proper form, are nevertheless undergoing an operation of repair, in which the old particles are withdrawn, whilst new ones replace them. We see with what care the walls of a house are shored up to admit of repair—how carefully the workman must estimate the strength of his pillars and beams—how nicely he must hammer in his wedges, that every interstice may be filled, and no

strain permitted; and if this operation fail in the slightest degree, it is attended with a rent of the wall from top to bottom. We say, then, that by the very awkwardness of this process, in which, after all, there is danger of the whole fabric tumbling about the workmen, we are called upon to admire how the solid pillars in our own frame are a thousand times renewed, whilst the plan of the original fabric is followed to the utmost nicety in their restoration. And if it deviate at all, it is only in a manner the more to surprise us, since, on examination, it will be discovered to result from an adaptation of the strength of material to some new circumstance, the increasing weight it has to support, or the jar that it is subject to, from the change in the activity or exercise of the body.

There is a disease of the bone which illustrates this in a surprising manner, and proves to us, that however diseased and monstrous in its shape the bone may be, yet there is a natural law operating, which by its prevalence will overcome the morbid action, and from a shapeless mass restore the bone to its natural condition.

This disease is called *necrosis,* which word signifies the *death* of the bone merely; but it is death in very peculiar circumstances; a new bone is formed around the old one; a large and clumsy cylinder is fashioned of the earth of bone; in the hollow of which the shaft of the old bone is contained. After a long time the old bone comes out through this new case, and with the aid of the surgeon, it is altogether withdrawn from the limb. During all this process the patient is capable of supporting his weight upon that limb, so that it resembles on a large scale that change which we have described as going continually on in the molecules of the bone; a new part is substituted, and the old taken away.

If workmen were to take away a pillar in the following manner, their work would resemble the process of necrosis: first, they must rear a hollow cylinder around the old pillar, resting on the plinth and base, and extending to the capital, and having secured the union of the cylinder at top and bottom to the extremities of the pillar, they must take away the shaft, or middle piece, of the old pillar by perforating the new cylinder.

The reader may easily imagine that when this process is completed in a man's limb it will be as clumsy as the leg of an elephant, large, firm, and shapeless; but the extraordinary circumstance is still to be described.—This new bone is gradually diminished in its exterior surface, and its hollow filled up, and thus, by a change scarcely perceptible, it resumes the form and dimensions of the original bone; and, after a time, the anatomist might examine this limb and find neither in the articulating surfaces, nor in the spines and ridges, nor in the points of attachment for ligaments and muscles any thing to indicate the extraordinary revolution that had taken place.

What explanation have we to give of this change? There can be no doubt that the material is not the same; for we have the old bone in our hand, and the man is walking upon a new bone. Yet extraordinary, then, as this appears, it is not more inexplicable than the common phenomenon of the growth of an infant to maturity. There is a living principle which is permanent while the material changes; and this principle attracts and arranges, dissolves and throws off successive portions of the solids. There is a law influencing this living principle, which, in its operation on the material, shapes and limits the growth of every part, and carries it through a regular series of changes, in which its form and aptness for its office are preserved, whilst the material alone is altered.

The influence of disease will for a time disorder this modelling process and produce tumours and distortions; but when at length the healthy action, that is the natural action, prevails, these incumbrances are carried away, and the fair proportions of the fabric are restored.

It is very pleasing to observe the different means employed where a slight change of circumstances demands it. This earth of bone—the phosphate of lime, is changing continually; but the teeth admit of no change; they consist of earth too—the phosphate, carbonate, and fluate of lime. Bodies calculated for such violent attrition, and with a surface so hard as to strike fire with steel, would be ill accommodated with such a property of changing as we have seen in the bones. They must therefore fall out and be succeeded by new ones; and this process, familiar as it may be, is

very curious when philosophically considered.

There are no teeth whilst yet the infant is at the breast; and when they rise they are attended with new appetites, and a necessity for change of food. When perfected they form a range of teeth, neat and small, adapted to the child's jaws and the size of its bones. Were they to grow at once, or to fall out at once, it would prove a disturbance to the act of eating. They fall in succession; their fangs are absorbed, they are loose and jangling, and are easily extracted. But now comes the question, why are these teeth of the infant old at six years? Why are those that are to succeed and be stationary for a series of years, to germinate and grow at the appointed time like the buds in the axilla of a leaf? And when fully formed, why do they remain perfect for sixty years instead of six; at the end of which term the first set were old and decayed? No difference can be observed in the material of the teeth of the first or second set. The one will be as perfect as the other after remaining a hundred years in a charnel house. Can any one refuse his belief, then, when he sees so accurate a mechanical adaptation of the teeth to their places and their offices; can he, we say, refuse assent to this also, that there is a law impressed—a property by which the milk teeth shall fail and be discharged from the jaw in six years, whilst the others will last the natural life of the adult, if not injured by accidents to which all parts are subject? This is not the only instance in which parts of the body lie dormant for a term of years, and are at a particular period of life developed and perfected —and which have, we may say, their time of infancy, perfection, and decay, whilst yet there is no material deterioration observable in the general frame.

We are thus brought to the consideration of a question which has not yet been fairly stated.

Those who say that life results from structure, and that the material is the ruling part, bid us look to the contrast of youth and age. The activity of limb and buoyancy of spirit they consider as a necessary consequence of the newness and perfection of organization in youth. On the other hand, a ruined tower, unroofed, and exposed to be broken up by alternation of frost and heat, dryness and moisture, wedged by the roots of ivy, and tottering to its fall, they compare with old age—with the shrunk limbs, tottering gait, shrivelled face, and scattered grey hair of the old.

But in all this there is not a word of truth. Whilst there is life and circulation there is change of the material of the frame, (and there is a sign of this if a broken bone unites or a wound heals.) Ascribe the distinction to the rapidity of change, to the velocity of circulation, or to the more or less energy of action; but with the antiquity of the material it can have nothing to do. The roundness and fulness of flesh, the smoothness, transparency, and colour of the cheek, belong to youth, as characteristic of the time of life, not as a necessary quality of the material! Is there a physiognomy in all nature—among birds and beasts, and insects and flowers—and shall man alone have no indication of his condition in the outward form and character?

The distinctions in the body, apparent in the stages of life, have a deeper source than the accidental effects of the deterioration of the material of the frame. The same changes which are wrought on the structure of the body in youth and in the spring of life are going on in the last term of life; but the fabric is rebuilt on a different plan. The law of the formation is still inherent in the life which has hurried the material of the body through a succession of changes; and each stage, from the embryo to the fœtus, the fœtus to the child, from that to adolescence, to maturity, and to the condition of old age, has its outward form, as indicative of internal qualities, but not of the perfection or imperfection of the gross material. We might as well consider the difference in the term of life of the annual or biennial plant as compared with the oak, or the ephemeris fly as compared with the bird that hawks at it, to be in the qualities of the matter which forms them, as that the outward characters of the different stages of human life arose from the perfection or imperfection of the material of the body. Not only has every creature its appointed term of life, but we have shown that parts of the human body do not, in this respect, bear a relation to the whole; organs are changed and disappear; others, in the mean time, at their regulated period, shoot to perfection, and again decay before the failure of the body. What can more distinctly

show that it is the principle of life that directs all; and that on it the law is imprinted which orders our formation, and all the revolutions we undergo. The material of the body, solid and fluid, is moved by this influence, and varies every day, part by part dying every hour, and renewed, until the series of its changes on the gross material of the body is accomplished in an entire and final separation.

The grand phenomena of nature make powerful impression on our imagination, and we acknowledge them to be under the guidance of Providence; but it is more pleasing, more agreeable to our self-importance, it gives us more confidence in that Providence, to discover that the minutest changes in nature are equally His care, and that "all things do homage."

Although it be true that every thing in nature, being philosophically contemplated, will lead to the same conclusions, yet the occurrences around us steal so imperceptibly on our observation, all the objects of nature, or at least vegetable and animal productions, grow up by so slow a process by our side, that we do not consider them at all in the same way as we should do if they started suddenly upon our vision.

It is this familiarity with the qualities of a living body, and a habit of seeing without reflection, which has made it necessary to carry the reader through so long a course of observation and reasoning to excite attention to the admirable structure of his own frame, and its adaptation to the earth we inhabit—to perceive that every thing is formed with a strict relation to the human faculties and organs, to extend our dominion and to multiply our sources of enjoyment. It is by seeing the plan of Providence in the establishment of relations between the condition of our being and the material world, that we learn to comprehend that unity of design in the creation in which we form so great a part.

This exaltation of our nature is not like the influence of pride or common ambition. We may use the words of Socrates to his scholar, who saw in the contemplation of nature only a proof of his own insignificance, and concluded "that the gods had no need of him," which drew this answer from the sage: "The greater the munificence they have shown in the care of thee, so much the more honour and service thou owest them!"

GENERAL INDEX.

[The references are given to the treatise or treatises in which the Article is to be found. Of the contractions *An. Phys.* stands for Animal Physiology; *An. Mech.* for Animal Mechanics; *Bot.* for Botany; and *Chem.* for Chemistry.]

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